Power conversion [2/2]
Lighting

Power and analog key program

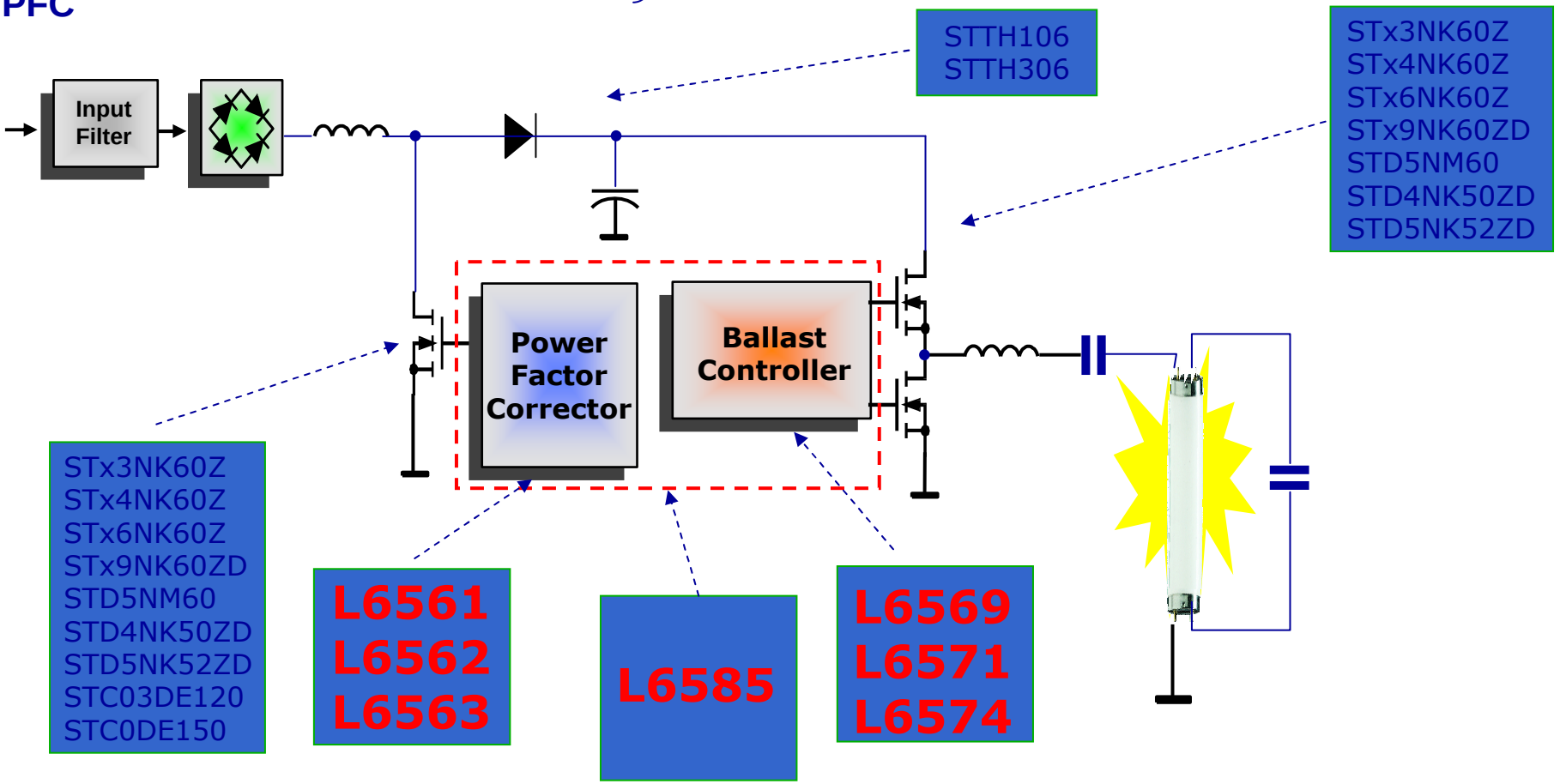
IPS & POWER CONVERSION - agenda

- **Power conversion**
  - SMPS
    - Main topologies quick roundup
    - Power Factor Correction
    - PWM (offline & HV DCDC)
    - Low Voltage DC-DC Converters
  - **Lighting**
    - **Fluorescent ballast**
      - **Analog driven**
      - **Digital driven / advanced**
    - HID
    - LED / DISPLAY DRIVER
      - DC / DC driven
      - Offline driven
      - Display control

Analog driven ballast for fluorescent lamp

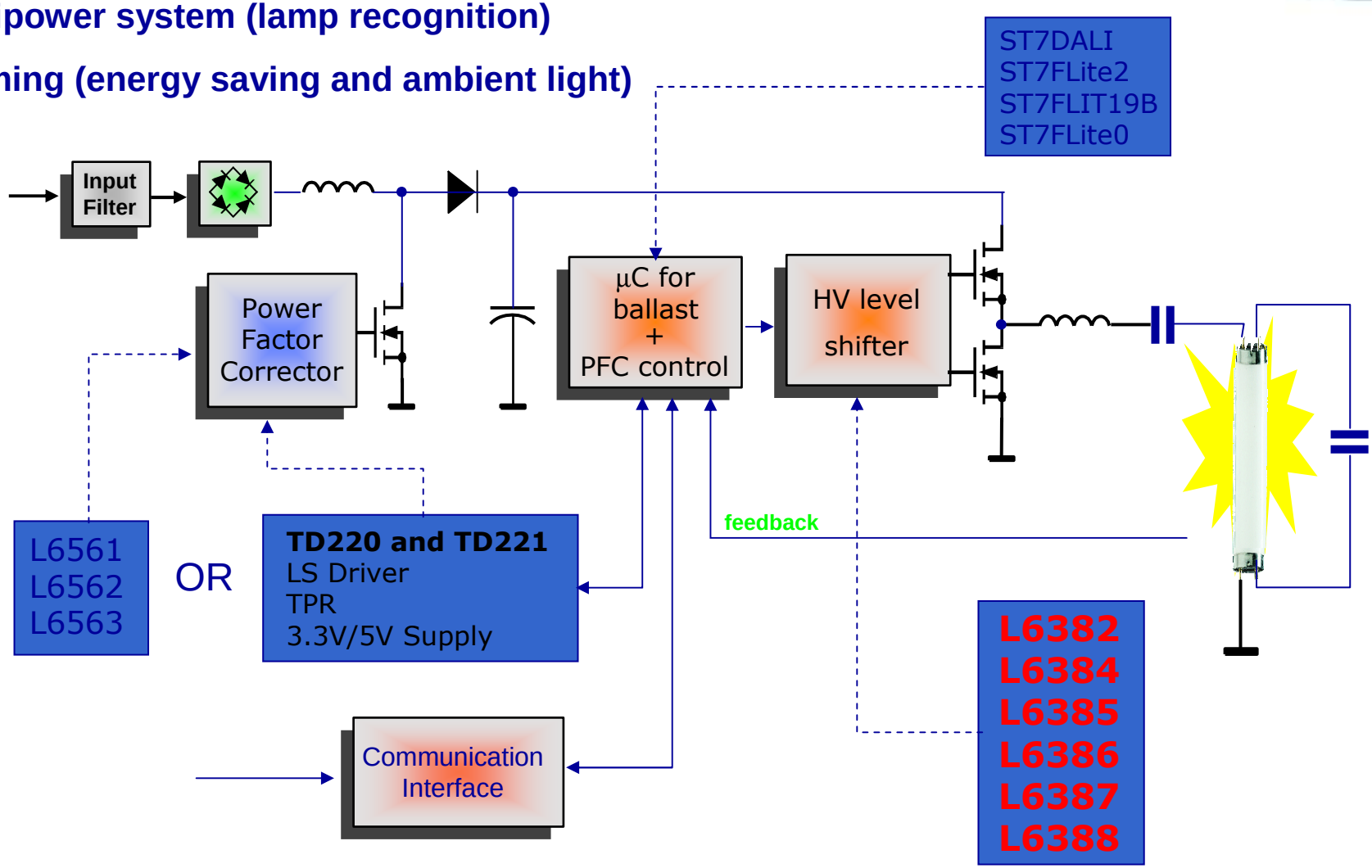
- fully controlled pre-heating/ignition
- Relamp
- Dimming
- End-of-life
- PFC

in a single chip



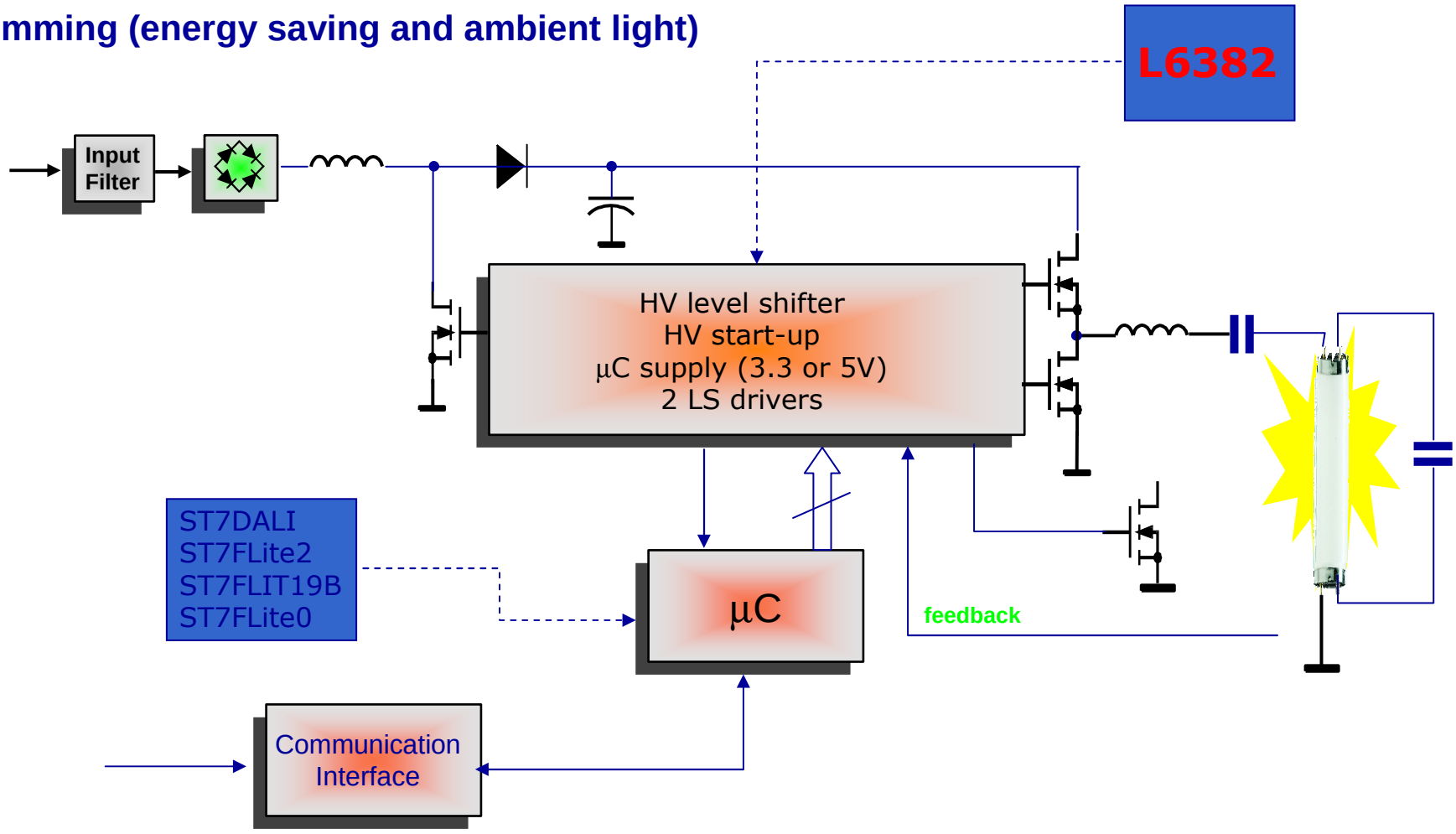
Digital driven ballast for fluorescent lamps

- **multipower system (lamp recognition)**
- **dimming (energy saving and ambient light)**



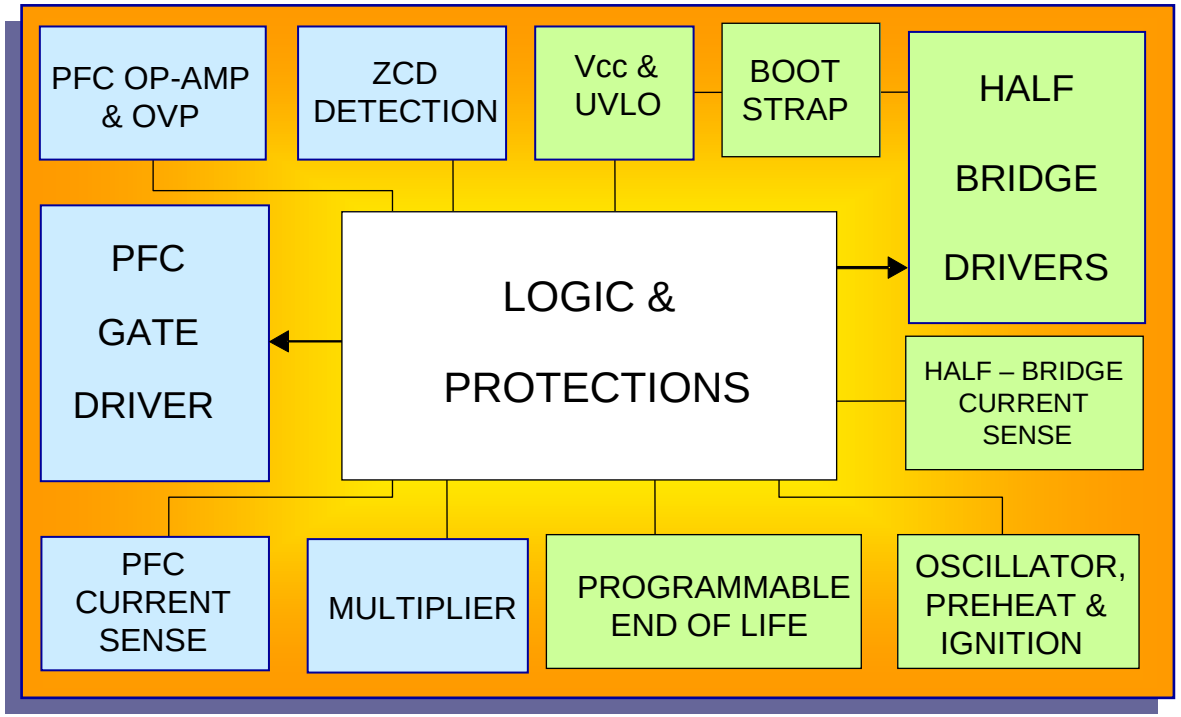
Advanced digital driven ballast for fluorescent lam

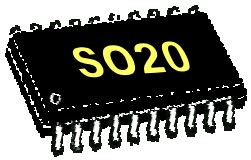
- multipower system (lamp recognition)
- dimming (energy saving and ambient light)



L6585DE - Block Diagram Overview

- ✓ PFC stage complete and reliable
- ✓ OVP* and feedback disconnection protection
- ✓ Anti choke saturation protection (allows the use of smaller PFC chokes)*
- ✓ Complete and independent programmability of frequencies and intervals*
- ✓ End of life*, rectification effect, capacitive mode and hard switching detection**
- ✓ Integrated bootstrap diode
- ✓ Shutdown pin*

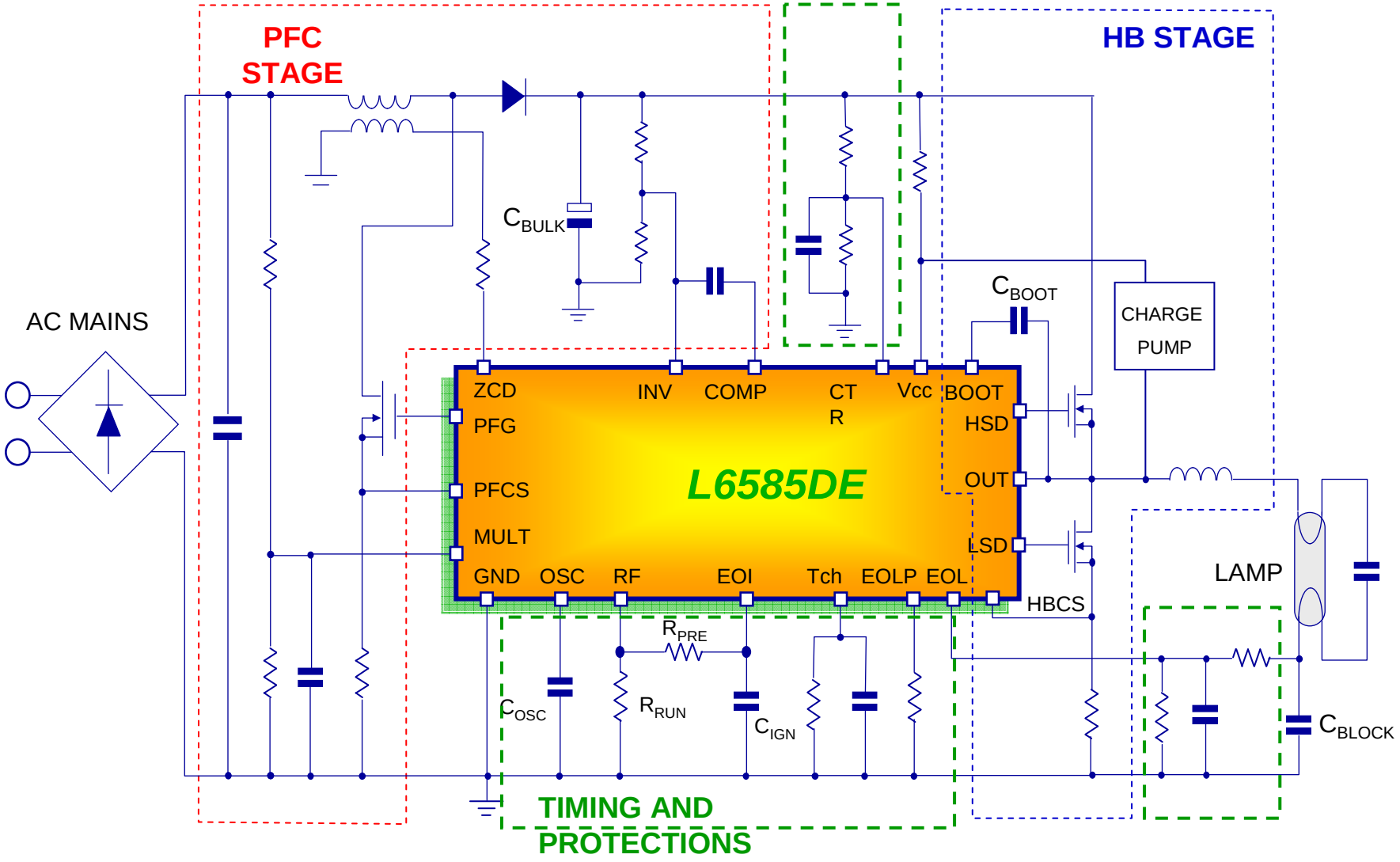




* Updated Feature

** New Feature

Application example



PFC section: features

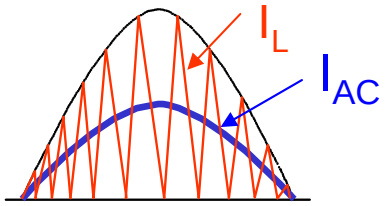
MULTIPLIER:
- ✓ sinusoidal reference
- ✓ superior PF performance
- ✓ Wide range-Mains operation optimized (THD optimizer)

ERROR AMPLIFIER
- ✓ Compensation network
- ✓ E/A inverting input
- ✓ Static OVP*
- ✓ Dynamic OVP
- ✓ Feedback disconnection
- ✓ IC shut down

ZCD network

HB INPUT

"TM" type



AC MAINS

ZCD COMP INV CTR

MULT

PFG

PFCS

L6585DE

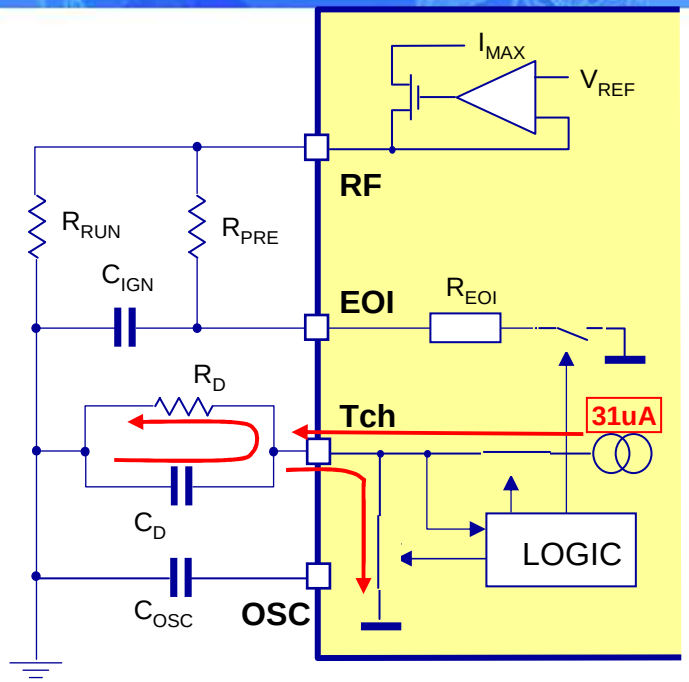
CURRENT SENSE:
- ✓ current mode control (1V clamp)
- ✓ choke saturation protection*
- ✓ leading edge blanking

GATE DRIVER:
- ✓ 300mA source (typ)
- ✓ 600mA sink (typ)

* Updated Feature

** New Feature

HB Section: Normal Starting sequence

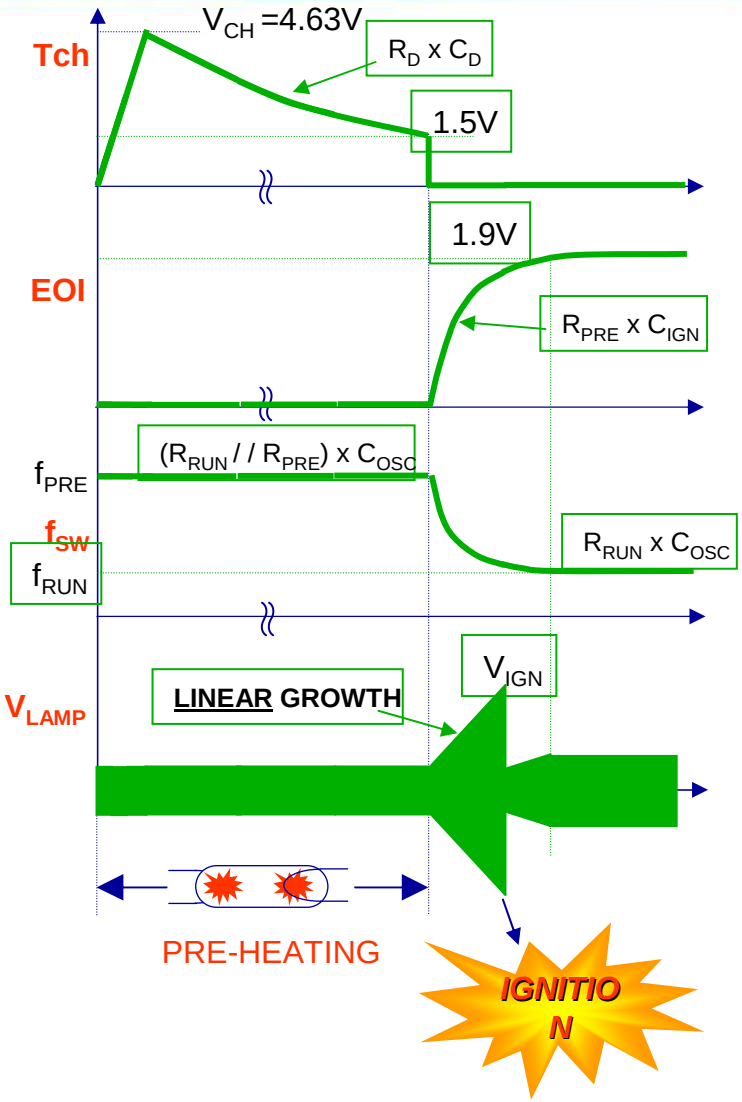


$$f_{PRE} = \frac{1.328}{C_{OSC} \cdot (R_{RUN} \parallel R_{PRE})}$$

$$T_{PRE} = 4.63 \cdot \frac{C_D}{I_{CH}} + R_D \cdot C_D \cdot \ln\frac{4.63}{1.52}$$

$$T_{IGN} = 3 \cdot C_{IGN} \cdot R_{PRE}$$

$$f_{RUN} = \frac{1.328}{R_{RUN} \cdot C_{OSC}}$$



HB section: HBCS pin Features

1. *Ignition*: → Controlled lamp voltage/current

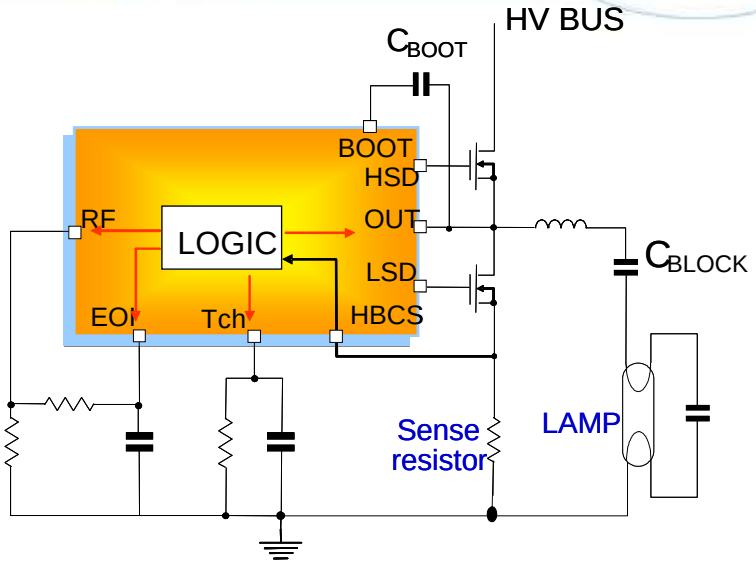
***Double threshold*:**

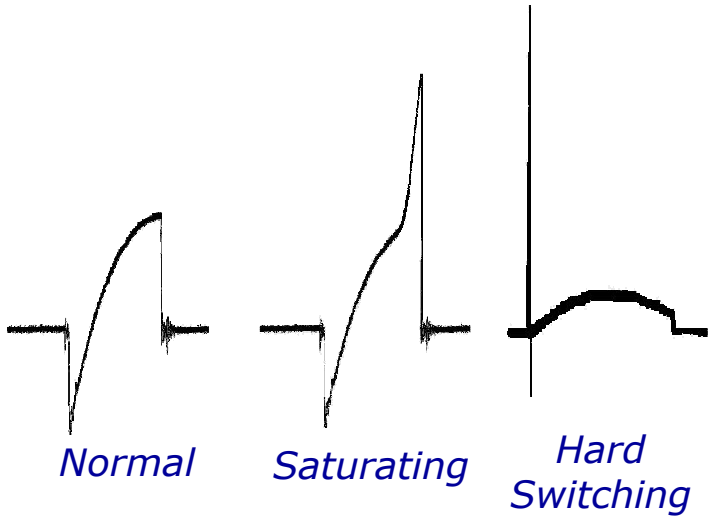
- **LOW (1.6V)*:** frequency increasing and Fast Tch cycle timing (externally programmable) to **limit the current in case of broken lamp or too old lamp.** Noise immune overcurrent detection method is used.
- **HIGH (2.75)**:** IC stops immediately **in case of capacitive mode caused by choke saturation**.

2. *Run mode* → 3 levels Over-current protection:

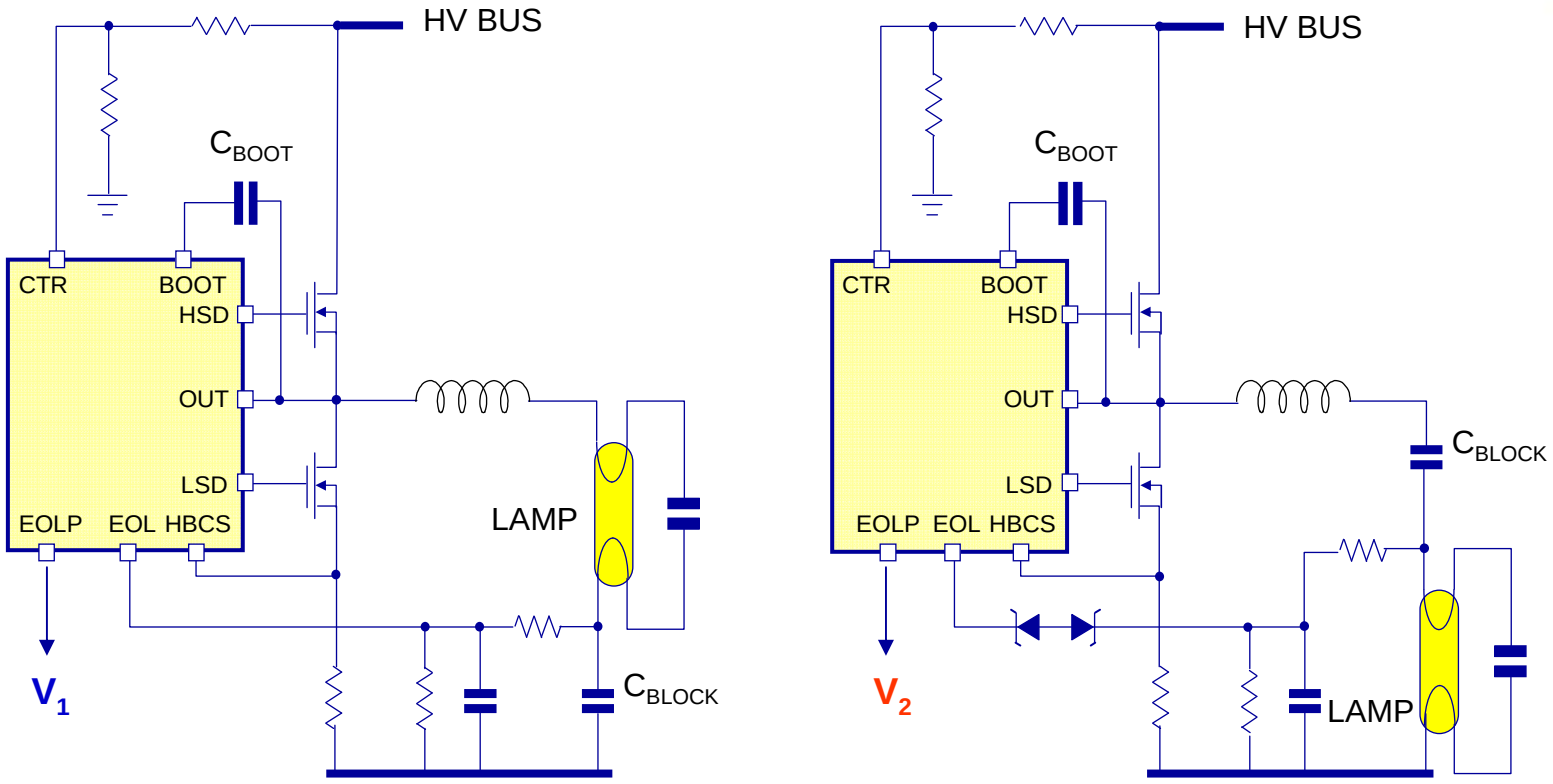
***Triple threshold*:**

- **LOW (0.9V)*:** frequency increasing and Tch cycle timing to **limit the current.** Noise immune overcurrent detection method is used.
- **MIDDLE (1.6V):** IC stops immediately when a long (300ns) hard switching pulse is detected **(Capacitive Mode protection – Lamp disconnection)**.
- **HIGH (2.75V)**:** IC stops after 350 subsequent hard switching pulses (40ns) in order to **prevent capacitive mode due to operation close to resonance**





HB Section: End of Life protection (EOL)



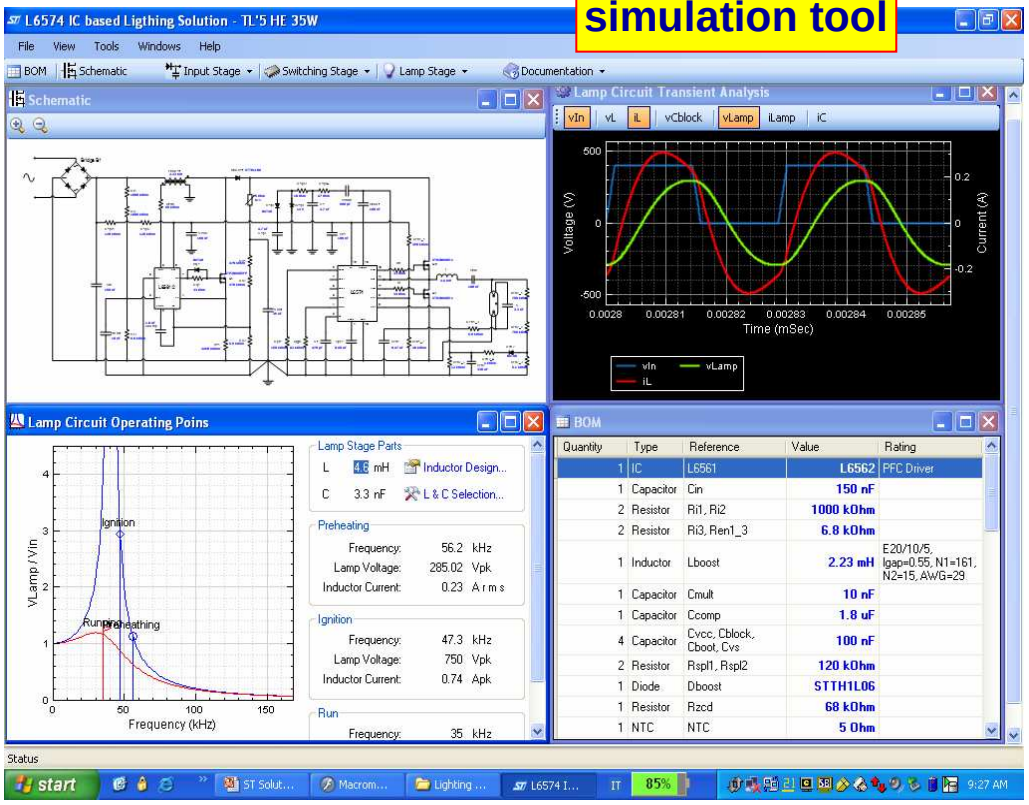
- ✓ Compliant with both standard ballast configurations without circuit change (using EOLP pin)
- ✓ Precise and programmable thresholds for the EOL intervention
- ✓ Filtering to delete noise effects

Support material

- Datasheet
- Demo board: STEVAL-ILB005V2
- IC Application Notes: AN2870 “Combo IC for ballast control”
- Developing software

STEVAL-ILB005V2

simulation tool



ST Lighting Designer: Overview

Start Window Highlights

- User Friendly Interface
- Many IC solutions available (Combo IC, L6574, L6569 or discrete)
- Most Used Lamp model available
- Three main input voltage range selectable
- Warm or Cold Ignition design
- PFC design
- Dimming feature (under development)

IPS & POWER CONVERSION - agenda

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  - **Lighting**
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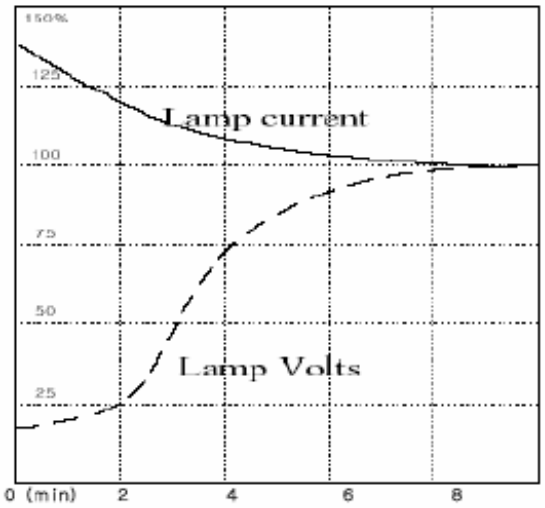
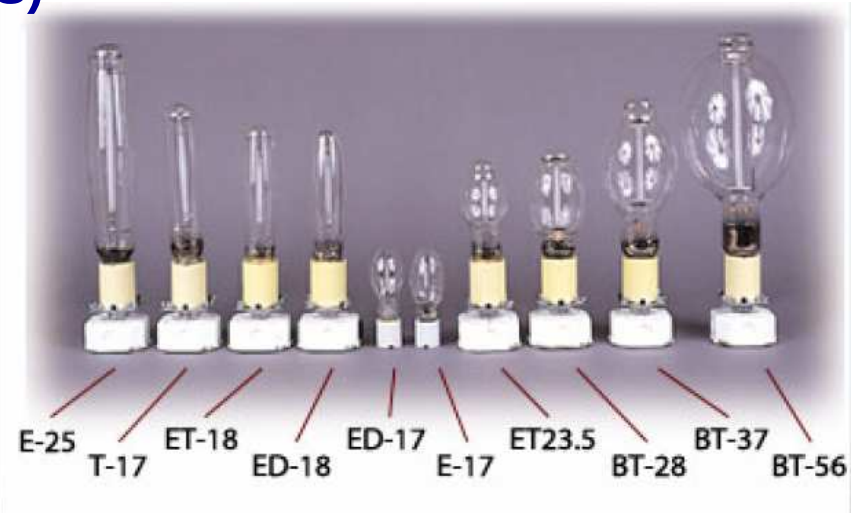
HID lamps

- **Metal Halide (MHD)**
  - high efficacy,
  - excellent color rendition,
  - long service life, and
  - good lumen maintenance.
  - outdoor applications and in commercial interiors



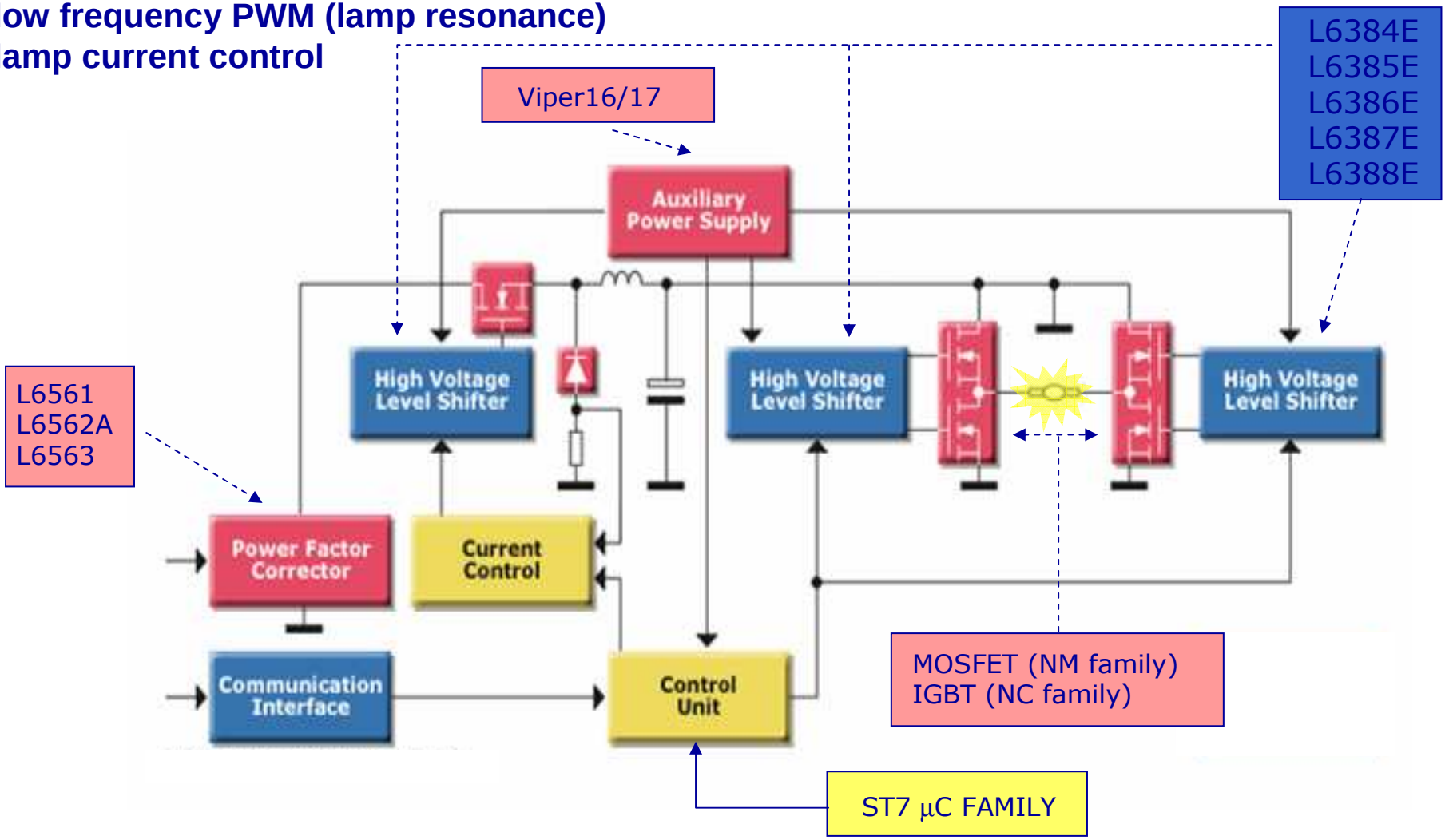
- **High pressure sodium lamps (HPS)**
  - energy efficient.
  - yellow/orange light
  - extremely good lumens per watt.
  - poor colors render
  - exceptionally long service life (up to 40,000 hours)



- **Mercury Vapor Mercury**
  - Poor colors rendering

Ballast for high intensity discharge (HID) lamps

- half / full bridge configuration
- low frequency PWM (lamp resonance)
- lamp current control



Sales description

STEVAL-ILH001V1

Documentation: AN2747 on Internet

- Input voltage: 90 - 265Vrms
- PFC working in a fixed off-time mode
- Ballast efficiency higher than 90%
- Output stage: Full Bridge working in continuous conduction mode
- Lamp driven with low frequency (160Hz) square waveform
- Lamp current controlled by high frequency (40kHz) buck converter

Key Products:

- ✓ STF20NM50N
- ✓ STG10NB60SD
- ✓ L6385E
- ✓ L6562N
- ✓ VIPer12AS – E
- ✓ STP12NM50FP
- ✓ STTH806TTI
- ✓ STTH1L06
- ✓ ST7FLITE39F2M3

Typical Applications:

- ✓ Street Lighting
- ✓ Retail Lighting
- ✓ Warehouses
- ✓ Industrial Lighting

Board Purpose:
To show full electronic solution replacing magnetic ballast with better efficiency and feature set

STEVAL-ILH003V1

Lighting

Coming soon

70W HID Lamp Ballast based on L6569A and L6562A

Features:

- 50/60 Hz 88V ~ 264V wide input voltage range
- Easily drive of a 70W metal halide lamp
- PFC working in Fixed-On-Time.
- Two-stage topology
  - Warming up state for start-up
  - Illuminate in steady state
- Dual Buck-Converter solution
  - Lamp driven with low frequency (200Hz) HB buck converter
  - Lamp current controlled by high frequency HB buck converter
  - Load power control technique
- Ballast efficiency higher than 88%

Driver: L6385ED

EVALUATION BOARD

www.st.com/evalboards

IPS & POWER CONVERSION - agenda

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    - **LED / DISPLAY DRIVER**
      - **DC / DC driven**
      - **Offline driven**
      - **Display control**

How to control LED Light output

There are two basic principles how the light output of the LED can be controlled. Since the light brightness is proportional to the current, both methods are dealing with current regulation. The first and the easiest way is to control the LED current itself, with the principal sketch in Figure 1, where current is changed proportionally with the dimming signal. Disadvantage of this analog control is that there can be a significant change of color (wavelength difference could be several nanometers) in deep dimming (less that 10%). This potential disadvantage is compensated by a very simple control circuit (usually a simple potentiometer is enough).

Figure 1. Analog current control

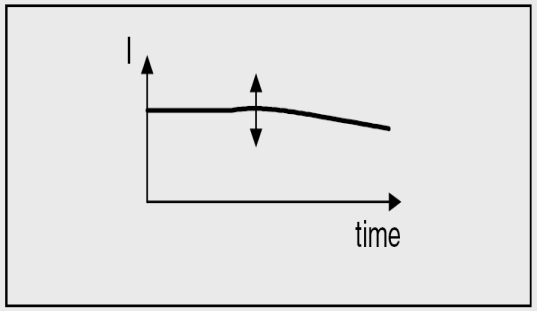
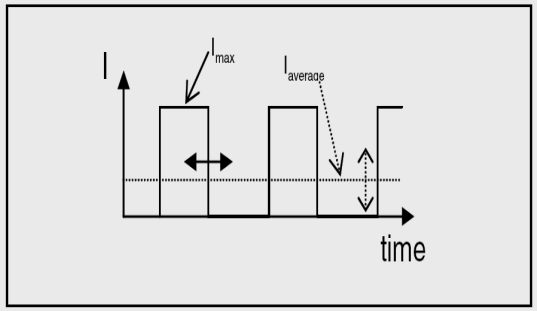
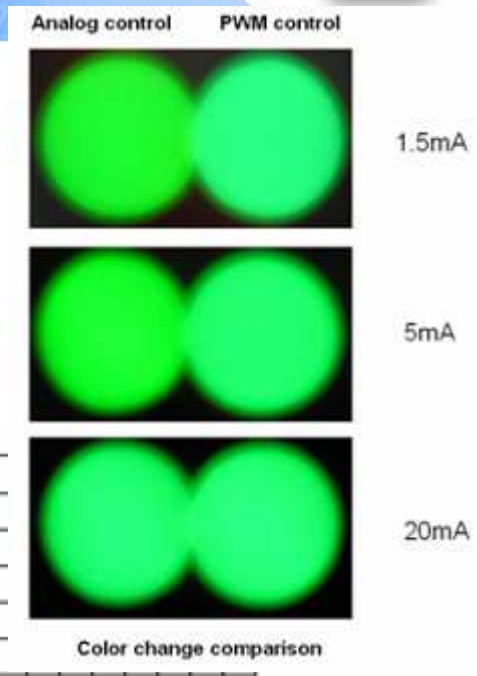


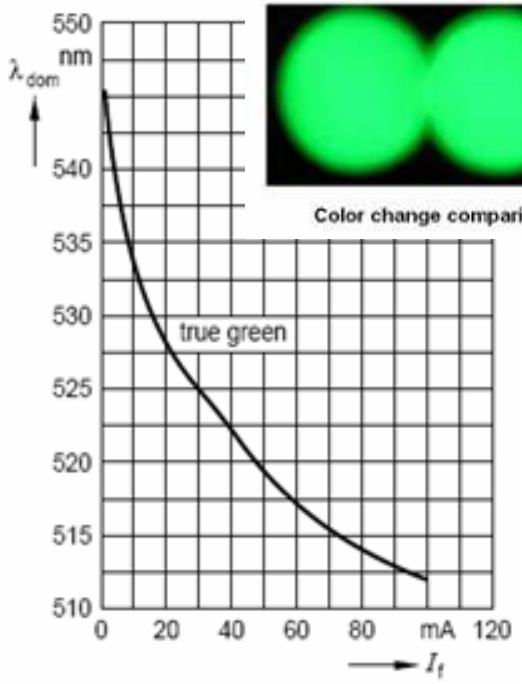
Figure 2. Average current control by PWM



The second method is based on an average current control (digital control) as can be seen in Figure 2. The current is switched between zero and the nominal current with a frequency higher than 100Hz (to avoid flickering). The change of duty cycle and hence the average current change will be seen as a brightness change, because human eye reaction is slow enough to "integrate" the light output and it will not be noticed as a blinking.

This method avoids the color change problem, but on the other hand it needs more sophisticated control circuits (usually a microcontroller or another simple PWM generator).





Current vs. wavelength characteristic
(Power TOPLED Datasheet - OSRAM)

LED Lighting and Norms

PFC: even when LEDs are used,
EN 61000-3-2 is valid for LED-Lighting too!

=> At output power ≥ 25W only with active PFC (Power Factor Correction) is this norm achievable

Solution for Color LED displays based on STP24DP05 and STM32

Advanced display LED array drivers, control and reference designs

Application examples

Signs

- Full-color
- Monochrome

Signals

- Traffic
- Other

Automotive

- Automobile exterior (stop/tail/turn lights)
- Automobile interior (instrumental panel and dashboard)
- Truck and bus exterior

Display backlighting

- PDAs, MP3 players and digital camera backlight
- Mobile phones displays
- Keyboard backlight
- Other displays

Specialty illumination

- Flashlights, headlights
- Architectural and design lighting
- Emergency lighting
- Water features and pools

Home Appliance

- System Indicator lights

Advertising

- Information panels
- Special light effects in shop windows

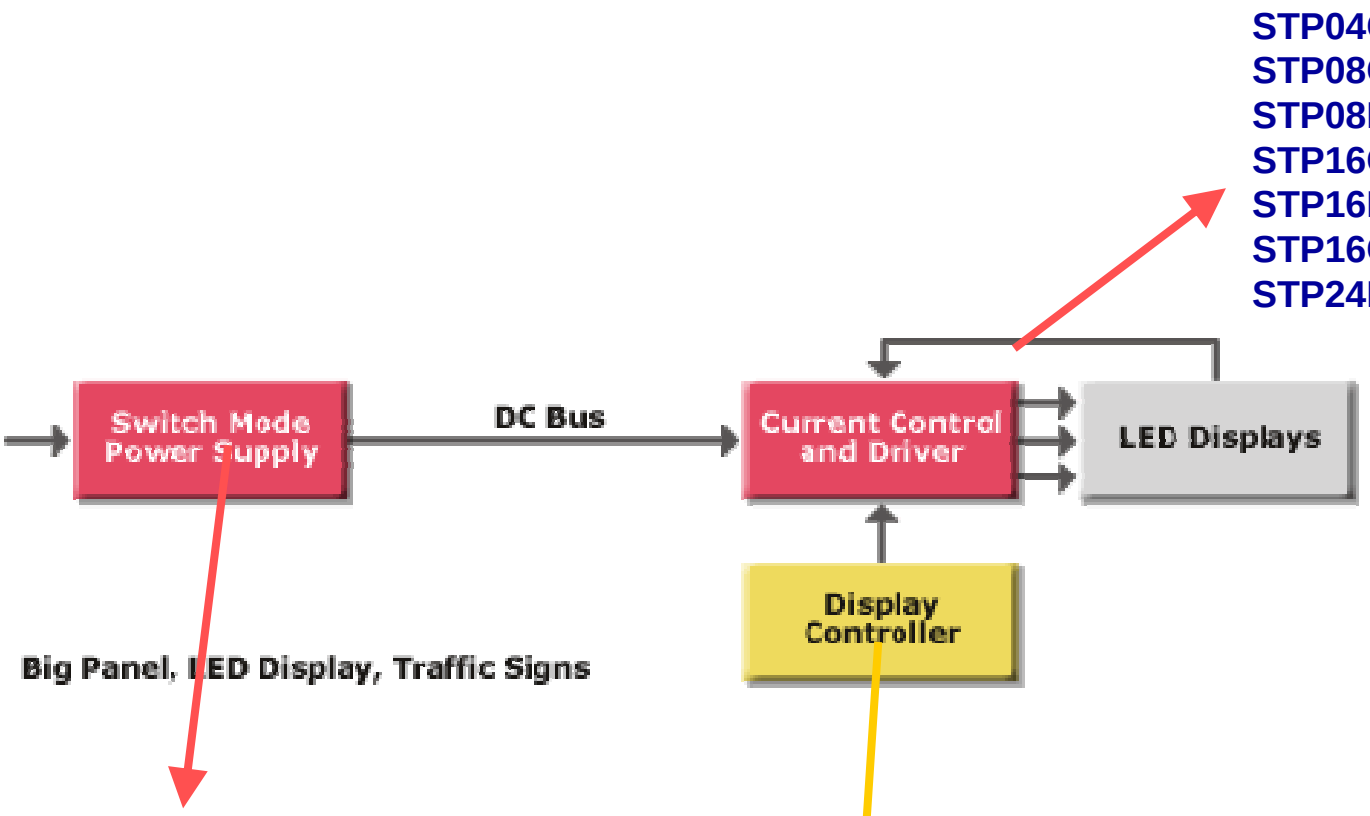
Industrial application

Applications for LED Display Drivers

Color LED displays, panels and signs

- Colored traffic signs
- RGB lighting for gaming and gambling machines
- RGB LED matrix displays
- LED advertisement billboards
- Graphic boards
- Variable message signs

LED Array
Big panel, LED display, Traffic signs,…



STP04CM05
STP08CP05
STP08DP05
STP16CP05
STP16DP05
STP16CPS05
STP24DP05

Viper Family
Current Mode CPWM Controller

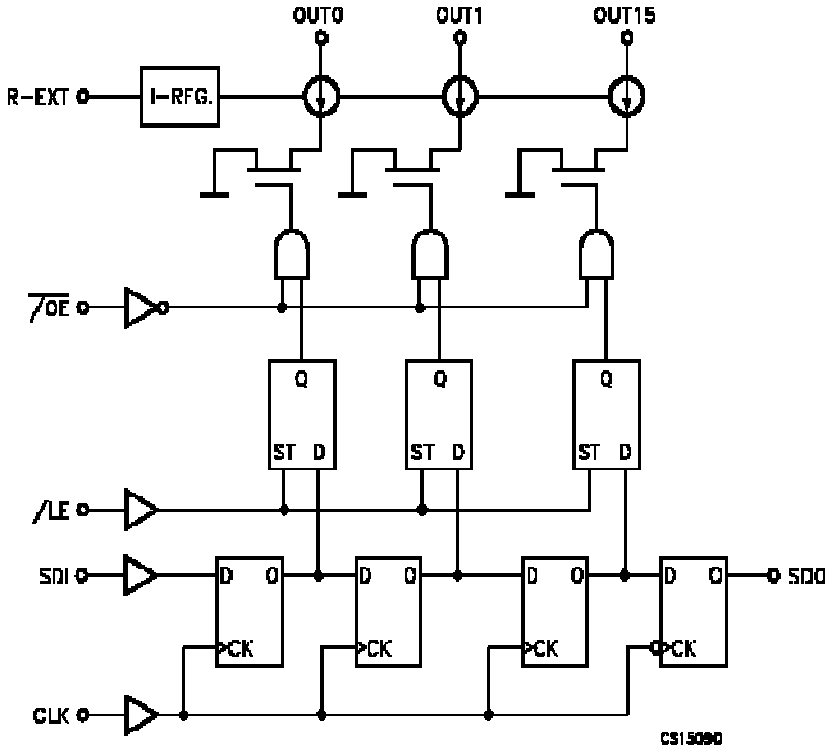
Microcontroller
ST7, STM8S
STM32

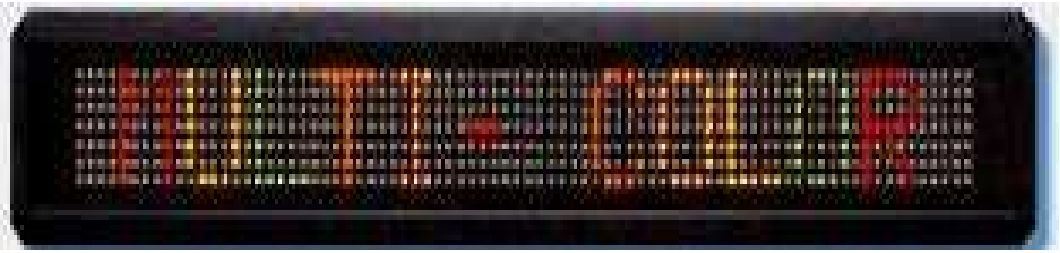
LED array sink drivers

Features:

- Low voltage power supply 3.0 to 5.5V
- Voltage capability at Outputs: 20V
- 4, 8, 16, 24 constant current output channels
- Adjustable output current through external resistor
- Serial data in / parallel data out
- Serial out changes state on the raising edges of clock
- Up to 30MHz clock frequency
- 3.3V micro driver-able
- Output current 3 – 500mA (depending on type of STPxxyy05)
- Thermal protection
- Auto Power save at STPxxCPS05
- LED failure detection at STPxxDP05
- Available in high thermal efficiency TSSOP exposed PAD

LED array sink drivers block diagramm

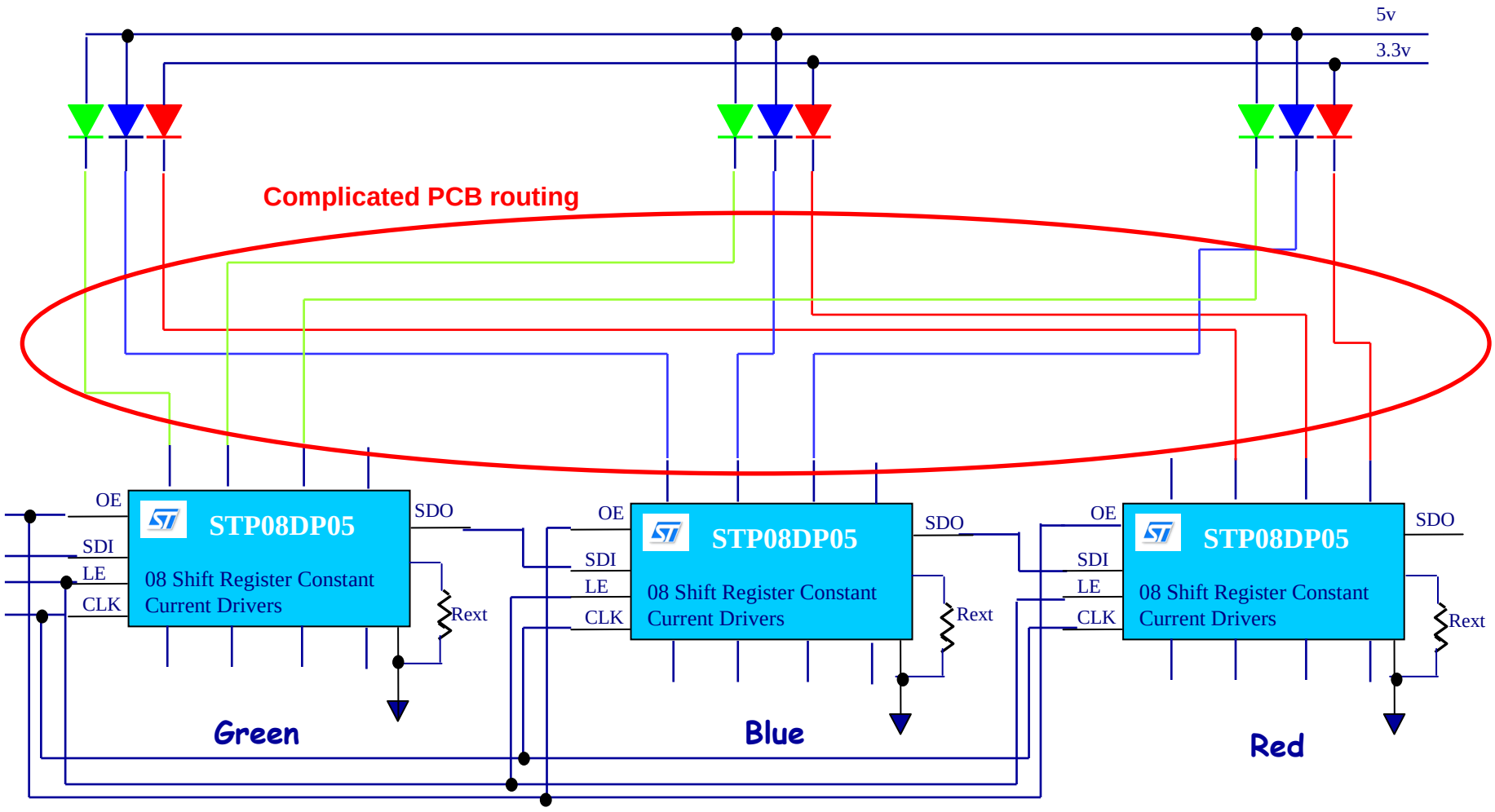




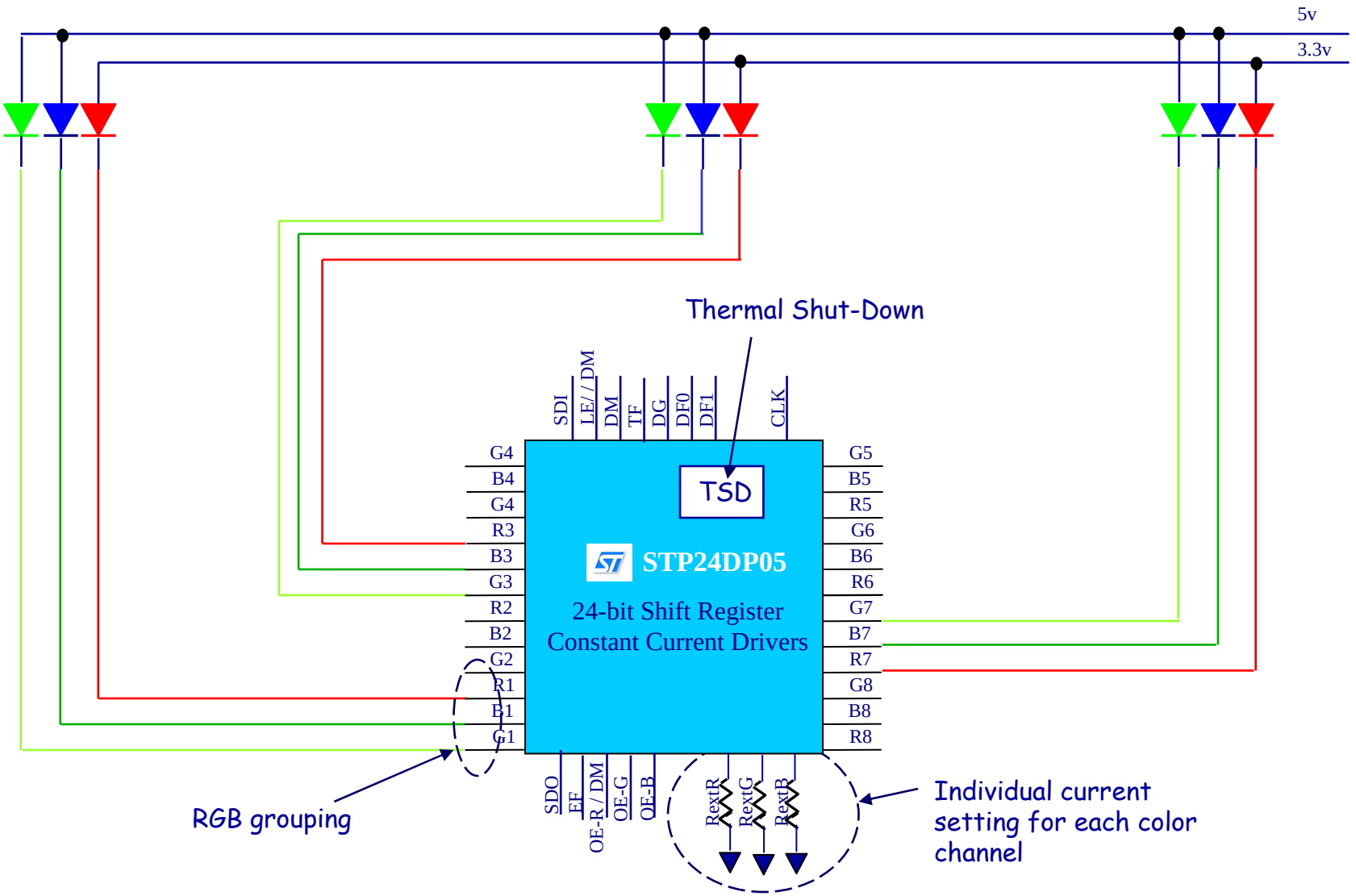
ST : a Complete Solution Portfolio

Part	Vin [VDC]	Iout [mA]	Vout [VDC]	No of channel	Remark	Ref Design	App Note
STP04CM05	3.3 to 5.5	50 to 500	16	4	SPI; dimmable current sinkPWM dimming, thermal protection	STEVAL-ILL009V1 STEVAL-ILL009V3 STEVAL-ILL009V4	AN2531
STP08CP05	4.5 to 5.5	5 to 100	20	8	SPI; dimmable current sink, thermal protection	(STEVAL-ILL003V1) (STEVAL-ILL003V2)	AN2141
STP08DP05	3.3 to 5.5	5 to 100	20	8	error detection; SPI; dimmable current sink, therm prot	STEVAL-ILL002V(1)/3 STEVAL – ILL002V(2)4	AN2415
STP16CP05	4.5 to 5.5	5 to 100	20	16	SPI; dimmable current sink, thermal protection	STEVAL-ILL003V(1)/2	AN2141
STP16CPS05	4.5 to 5.5	5 to 100	20	16	SPI; dimmable current sink, thermal protection Auto Power Save	STEVAL-ILL003V(1)/2	AN2141
STP16DP05	3.0 to 5.5	5 to 100	20	16	error detection; SPI; dimmable current sink, therm prot		AN2141
STP24DP05	3.0 to 5.5	5 to 100	20	16	error detection; SPI; 3 currnet source values, dimmable current sink, therm prot	STEVAL-ILL015V1	AN2141
STPIC6A259	4.5 to 5.5	350	33	8	SPI; Automotive		
STPIC6C595	4.5 to 5.5	250	33	8	SPI; Automotive		
M5450x / M548x	4.75 to 13	25	13	34 / 35	Adjustable current sink		

STP24DP05
Limitation on current solutions for full-color Display



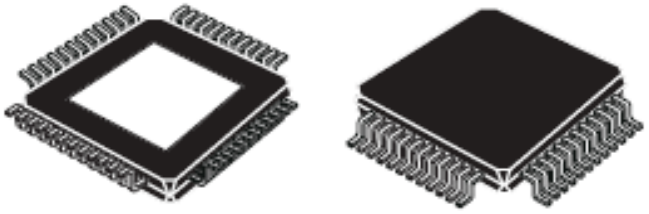
STP24DP05 Advantages of 24-channel solution



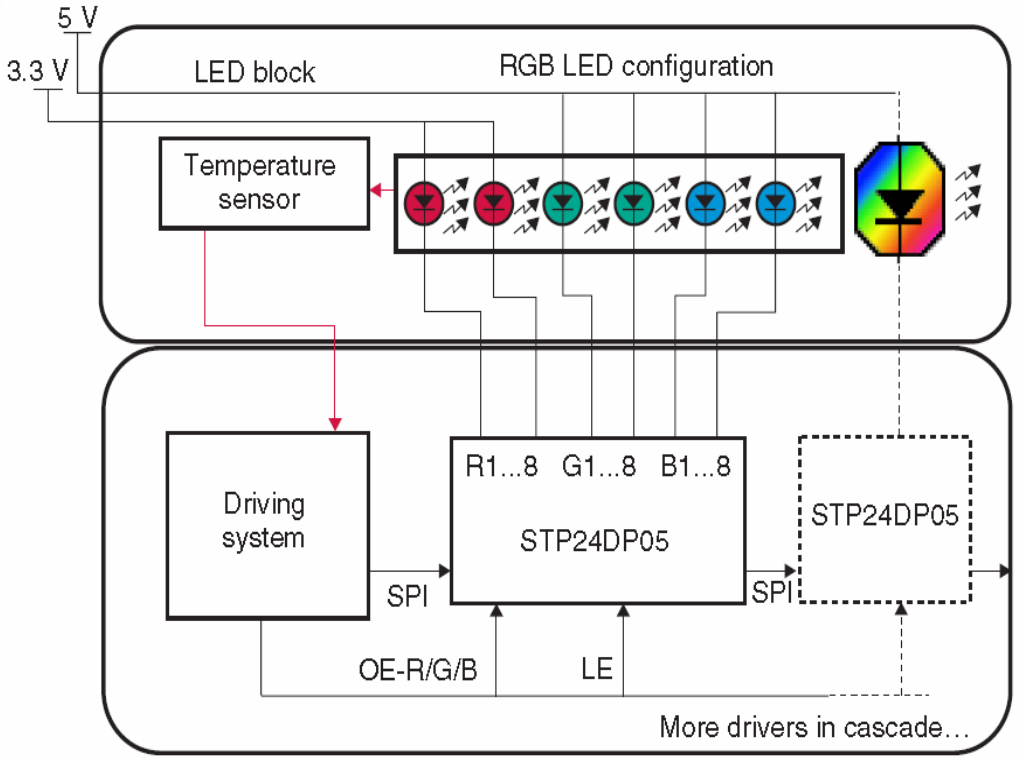
STP24DP05 Basic Features

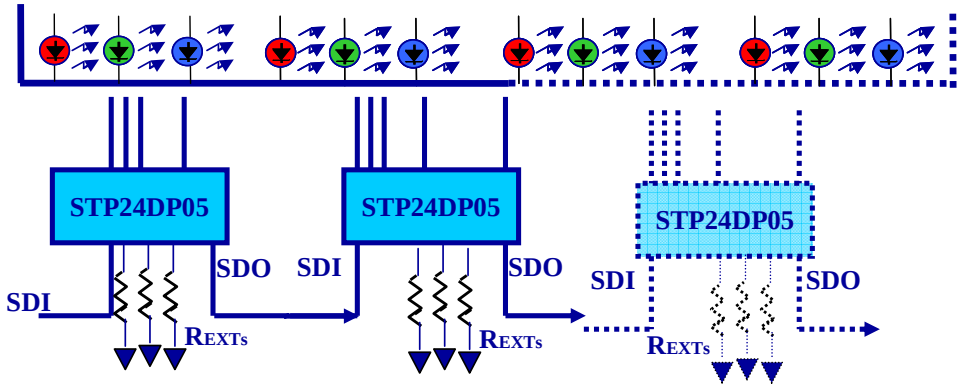
Key Features

- *Accept 3.3v and 5v micro driver*
- *8 x 3 Channel groups of constant current output channels*
- *Adjustable output current through one external resistor for each group of 8-channel*
- *Short and Open Output Error Detection via SPI and flag pin*
- *Serial Data IN / Parallel Data OUT*
- *SPI Serial Interface*
- *Gradual Output Delay*
- *Thermal Shutdown with flag pin*
- *Excellent Current Accuracy*
- *Output Current: 5-80mA*
- *25MHz Clock Frequency*



TQFP48





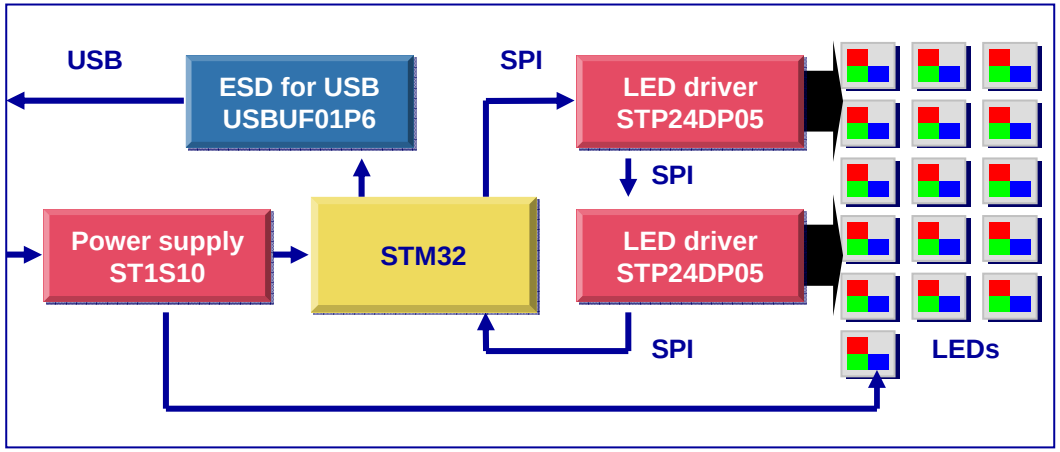
Purpose of Reference Designs of LED Array

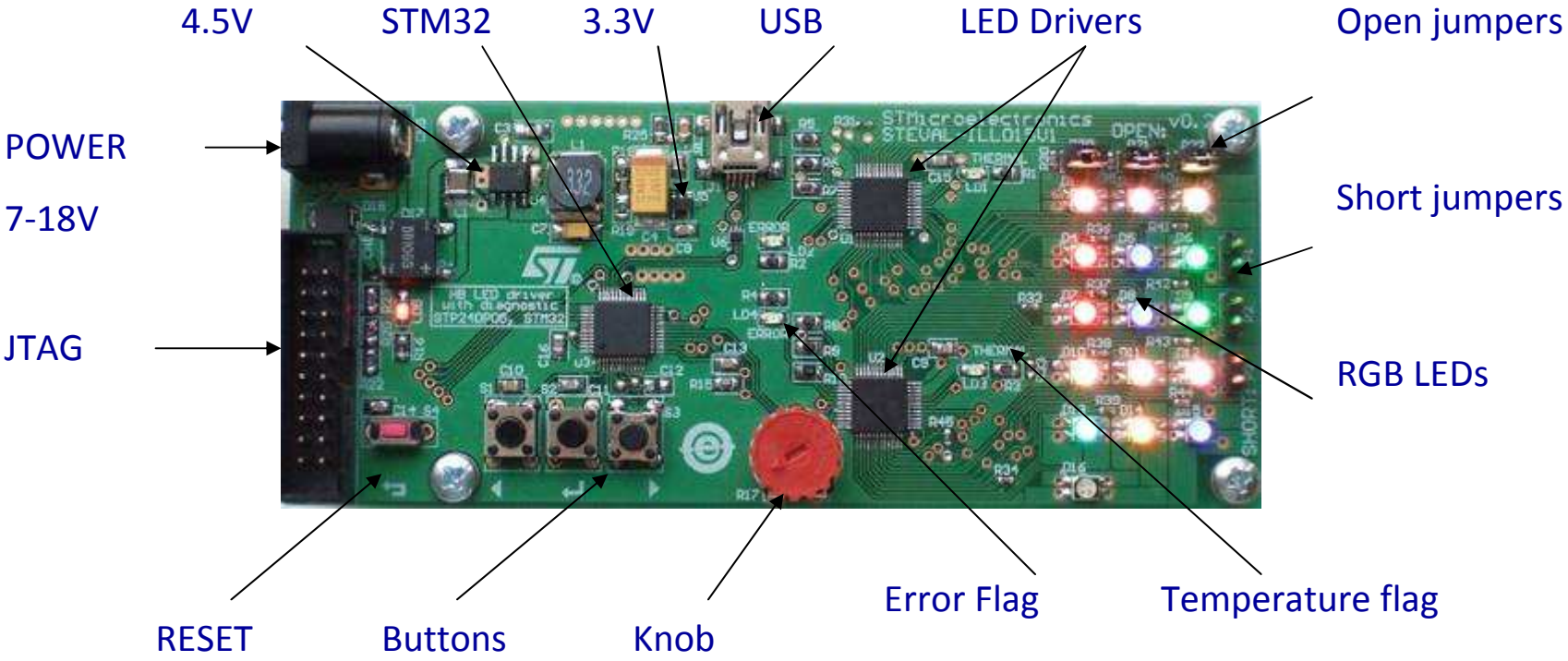
- **Aimed to customers working on applications with high number of low power LEDs**
  - either color or monochromatic
- **Open software architecture - easily integrates Demo**
  - USB and JTAG programming connectivity to use the board as a simple development tool
- **Gerber Files, PC Software,... : available**

- **Here as example : STEVAL-ILL015V1**
  - 6-rows 30mA LEDs driver with buck regulator
  - Applications: Indoor or outdoor use, LED advertisement billboards, Graphic boards, Colored traffic signs, Variable message signs…
  - Key Products: STP24DP05, STM32F103, ST1S10
  - Documentation: AN2841, UM0574 & UM588 published

STEVAL-ILL015V1 Block description

Reference design





STEVAL-ILL015V1
Functionality #1 - PC Interface

Reference design

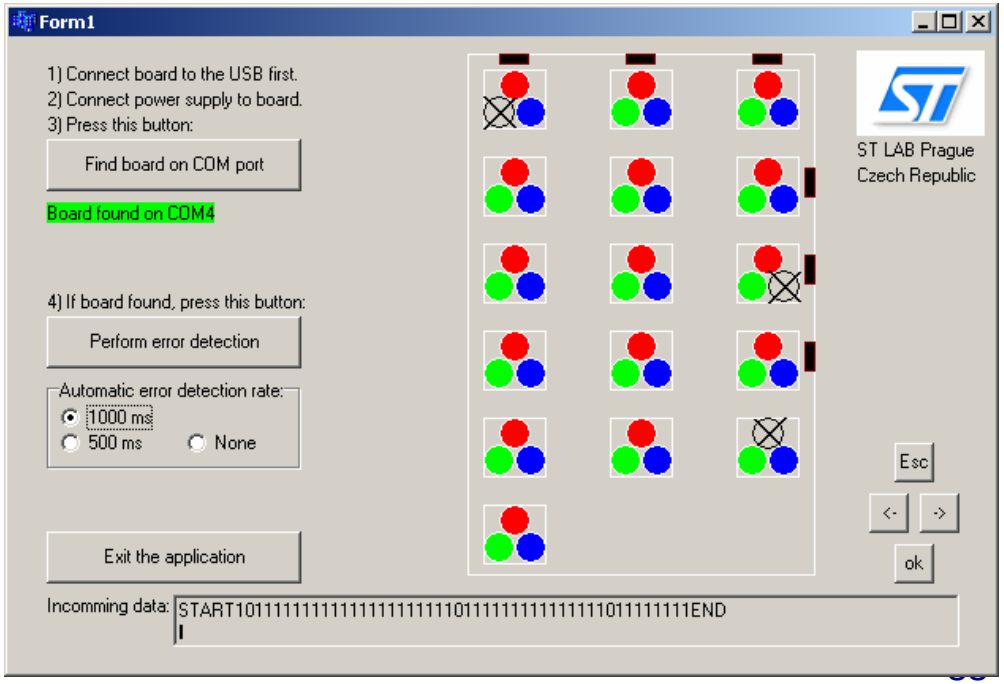
Firmware modes:

- 8-bit resolution mode for each color
  → 16 million colors demonstration
- Animated text menu:
  Simple game, Wave color demo, Solid color demo, LED diagnostic

Software features:

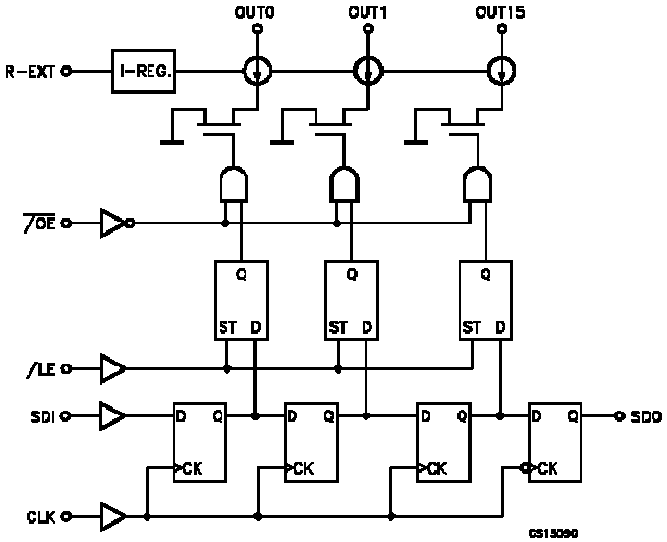
- USB interconnection, Virtual comport driver used
- LED diagnostic during any running firmware demo
- Demoboard firmware mode control by on-screen buttons instead of on-board buttons

USB

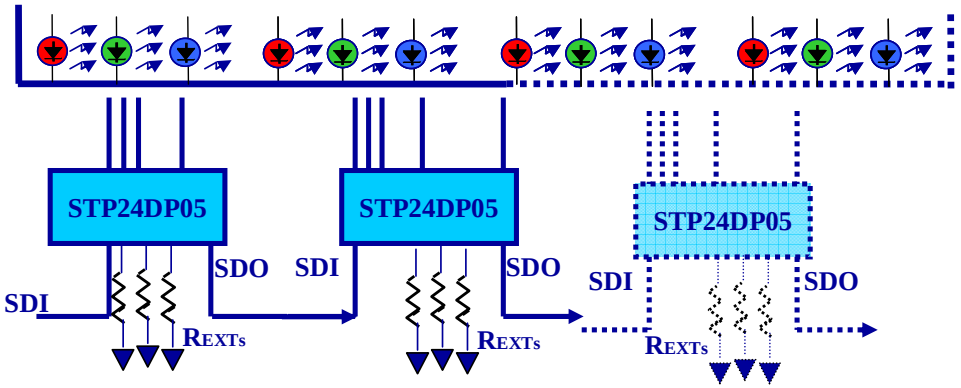


STEVAL-ILL015V1
Functionality #2 - LED dimming using shift registers

Application Know-how

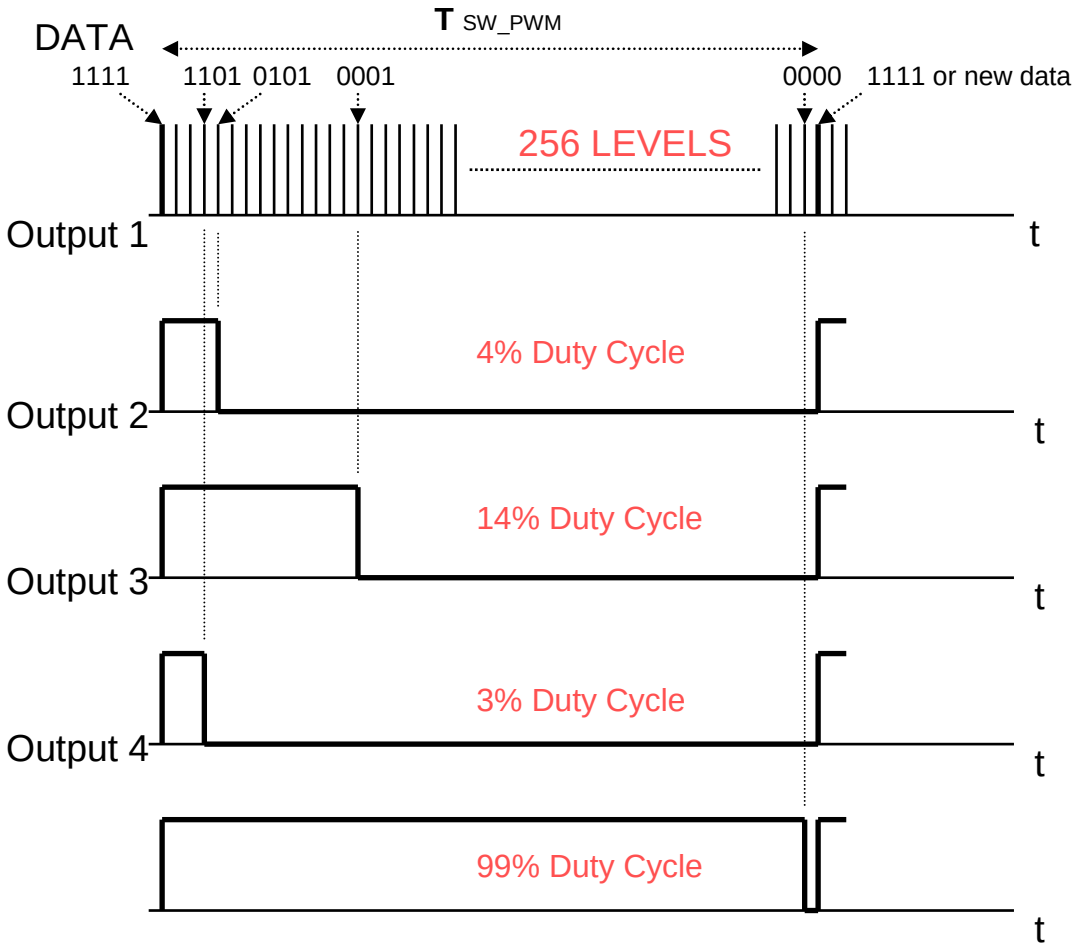


Shift Register LED Driving Principle

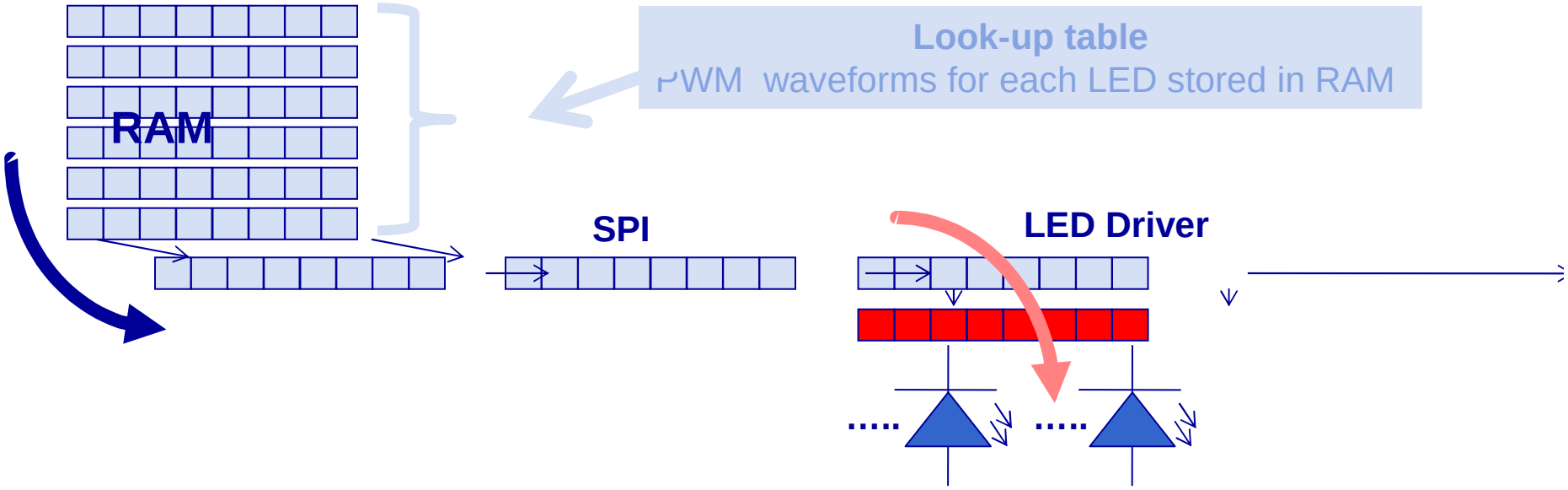


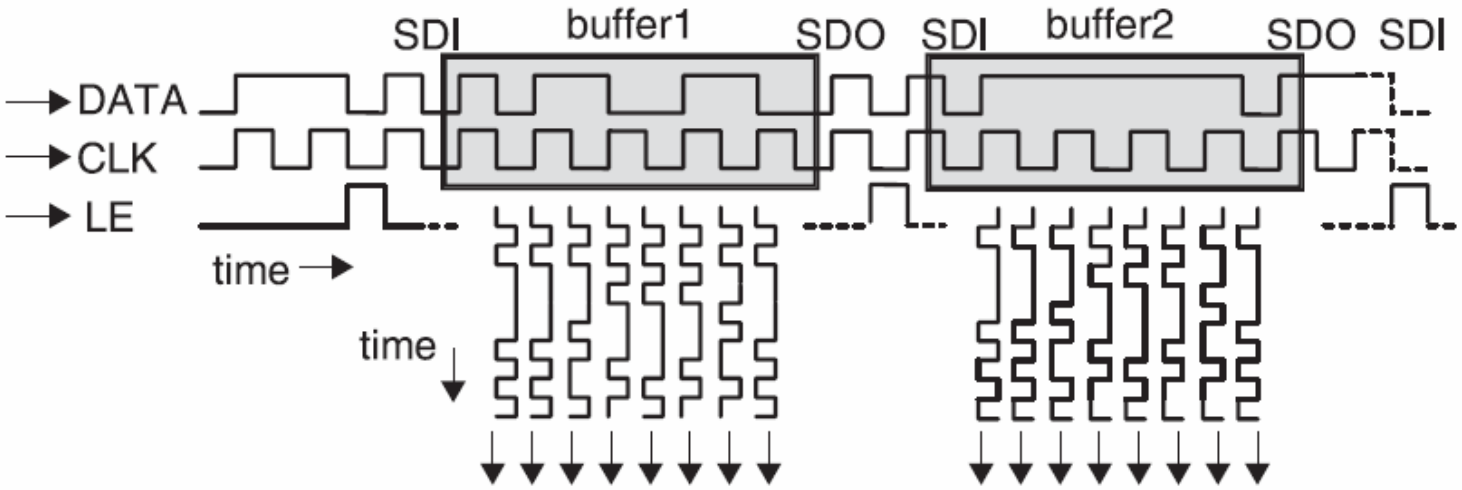
Cascading Principle

Example for 4-channels – 8bit resolution dimming



STEVAL-ILL015V1
Functionality #2 - LED dimming using shift registers



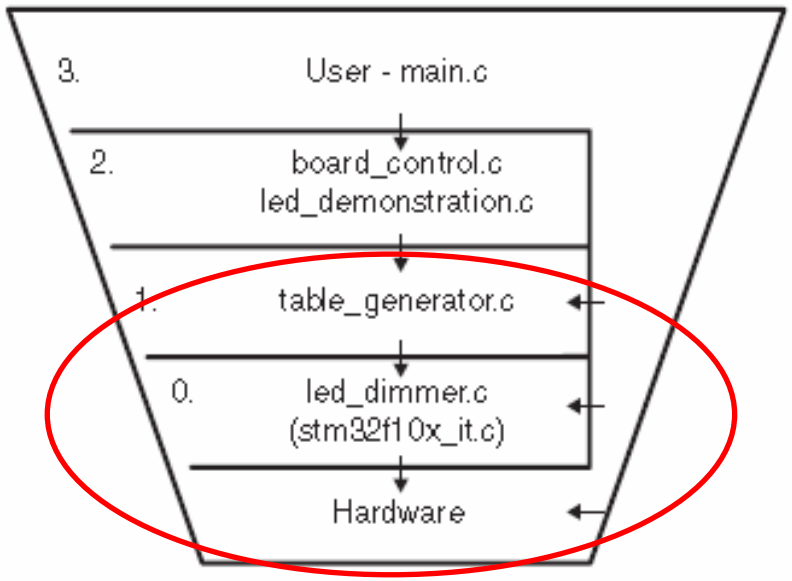


Make the designer's life easier!

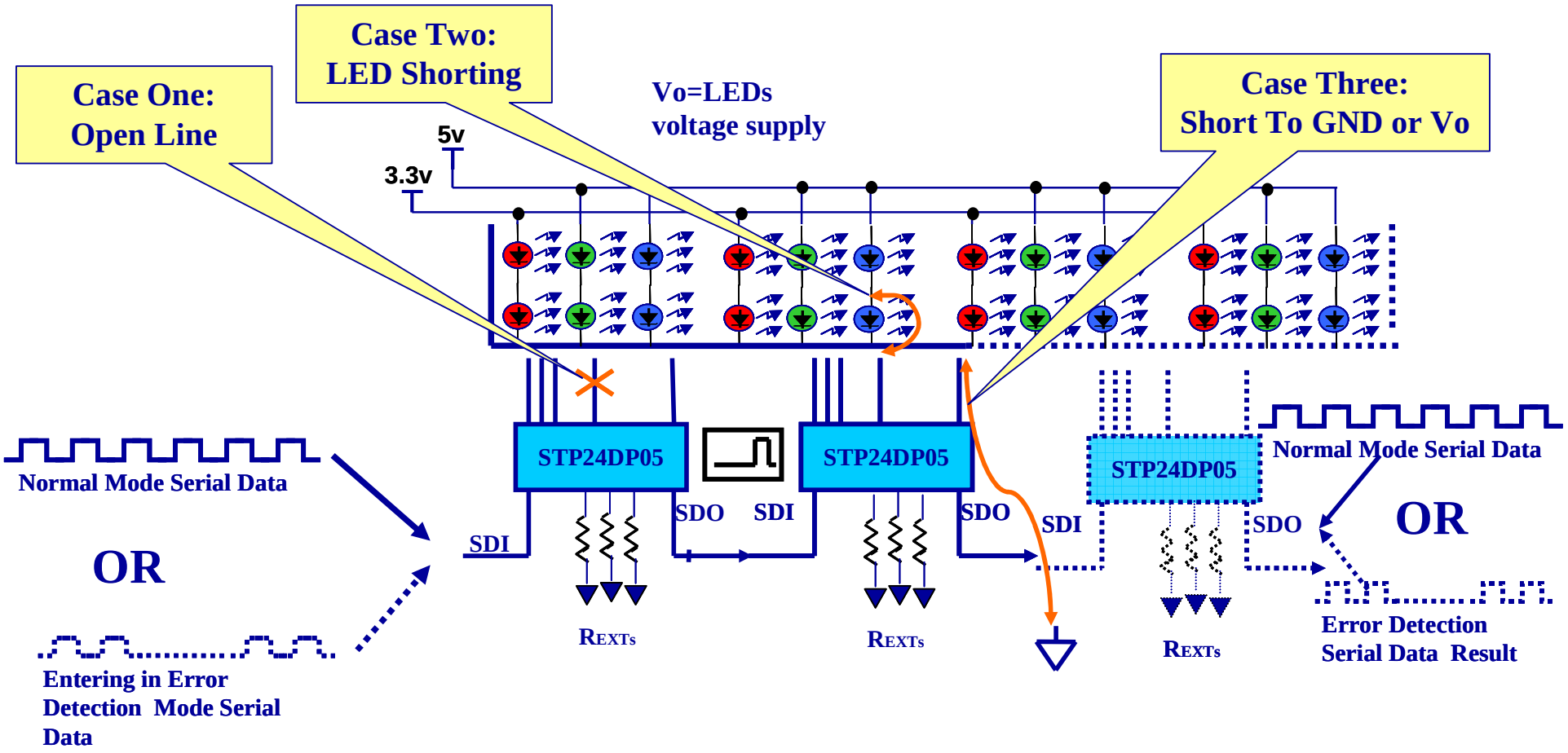
UM0588 – dimming C library user manual

Library key features:

- source files for **STM32** and **STM8**
- peripheral pre-setting (timer, DMA, SPI) to requested values
- timer running on background (interrupt (STM8) or interrupt + DMA (STM32))
- simple addition of customer foreground and background tasks
- brightness and color of each LED defined by three (R, G, B) variables



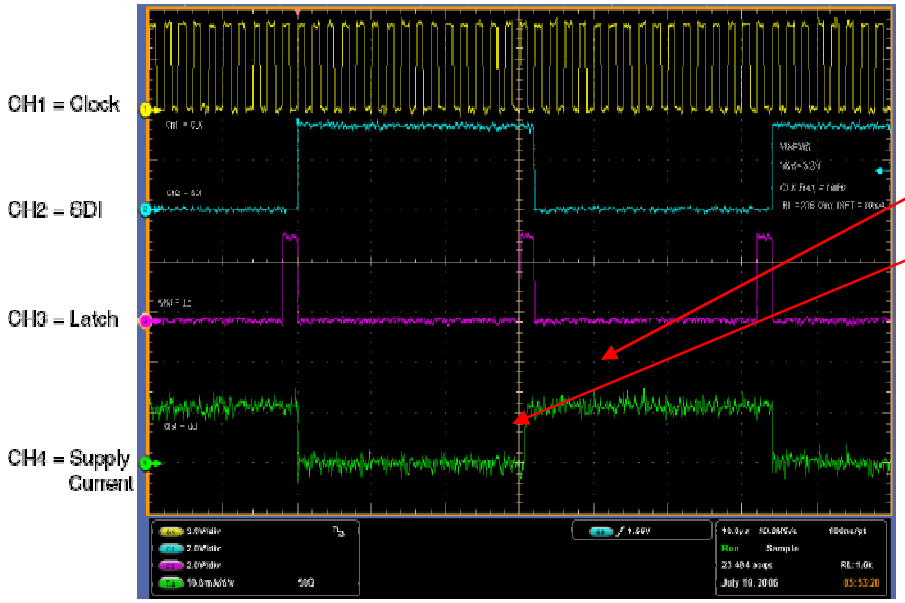
STEVAL-ILL015V1
Functionality # 3: Output Error Detection



Tools and Documents

- **Reference Design STEVAL-ILL015V1**
- **Application Note: AN2841**
- **User Manuals:**
  - UM0574 HW
  - UM0588 C Firmware library
- **Datasheets**
  - STP24DP05
  - STM32F103
  - ST1S10

STP16CPS05: Autoshutdown functionality: A hypothetical case…



$I_{DD\ (ON)}$ = 11.7mA (typ)

$I_{DD\ (Shut\text{-}down)}$ = 100uA (typ)

$I_{CC(SHUT\text{-}DOWN)}$ is 117 times less than $I_{CC(ON)}$

Power Savings – An example

- LED panel size : 10m x 5m
- Estimated number of LED Drivers : 10,000 pcs
- LED drivers active at any one time : ~ 20%

X Using std LED driver ➔ All 10,000 will consume high current (approx 117 A)

√ Using STP16CPS05 ➔ Only 2,000 will consumer high current (approx 23 A)

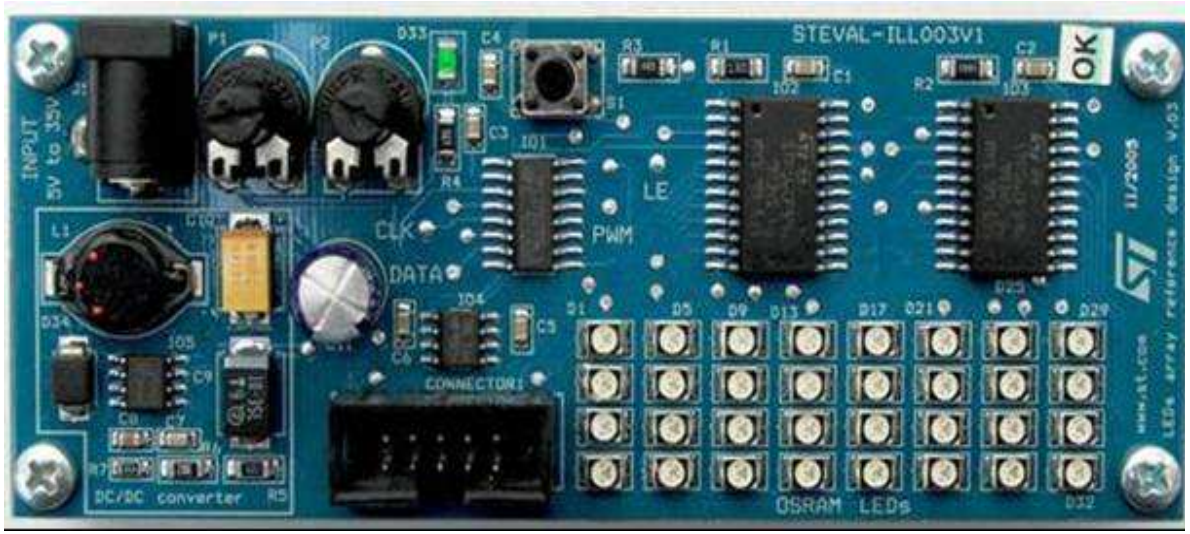
Power savings using STP16CPS05 is ~ 80 %

32 LED array evalution board (without diagnostic) based on advanced logic STP16CP05 and STP16CPS05

Documentation: AN2141

Features:

- 32 LED Matrix is driven
- Adjustable Brightness
- Led current regulation
- Adjustable blinking speed
- Different blinking modes
- Animated text
- Input voltage from 5V to 35V
- DC/DC Pre-regulator for high efficiency



Key Products:

✓STP16CP05
✓STP16CPS05
✓ST7FLITE09
✓L5970D
✓L78L33

Typical Applications:

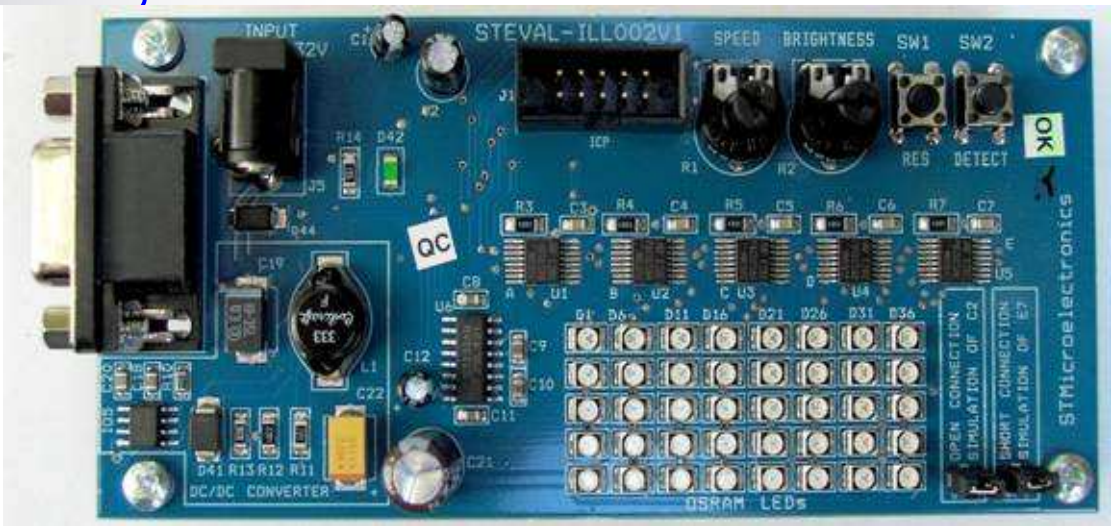
✓LED Information Panels
✓LED Displays
✓Traffic Signs
✓Signals
✓Decorative Lighting
✓Home Appliances (White Goods)

STEVAL-ILL003V2

40 LED array evaluation board (with diagnostic) based on advanced logic STP08DP05

Documentation: AN2141, AN2415, AN2478

OSRAM LEDs



Features:

- 40 OSRAM BLUE LED Matrix is driven
- Open and Short Line error detection
- Adjustable Brightness
- Led current regulation
- Adjustable blinking speed
- Different blinking modes
- Animated text
- DC/DC Pre-regulator for high efficiency

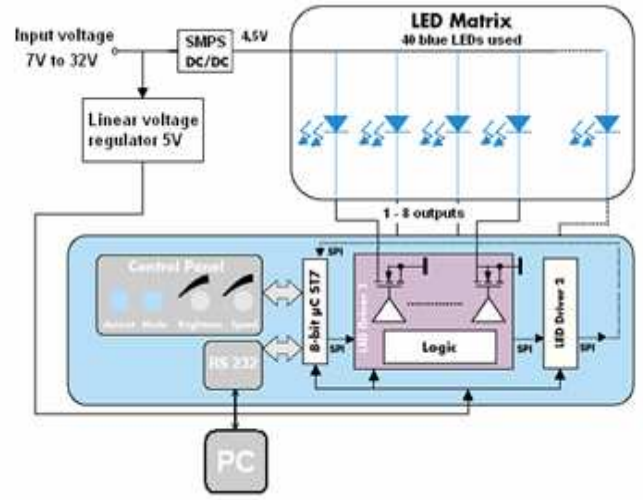
Key Products:

✓ST7FLITE
✓STP08DP05
✓ST232
✓L5970D

STEVAL-ILL002V3

Typical Applications:

✓LED Information Panels
✓LED Displays
✓Traffic Signs
✓Signals
✓Decorative Lighting
✓Home Appliances (White Goods)



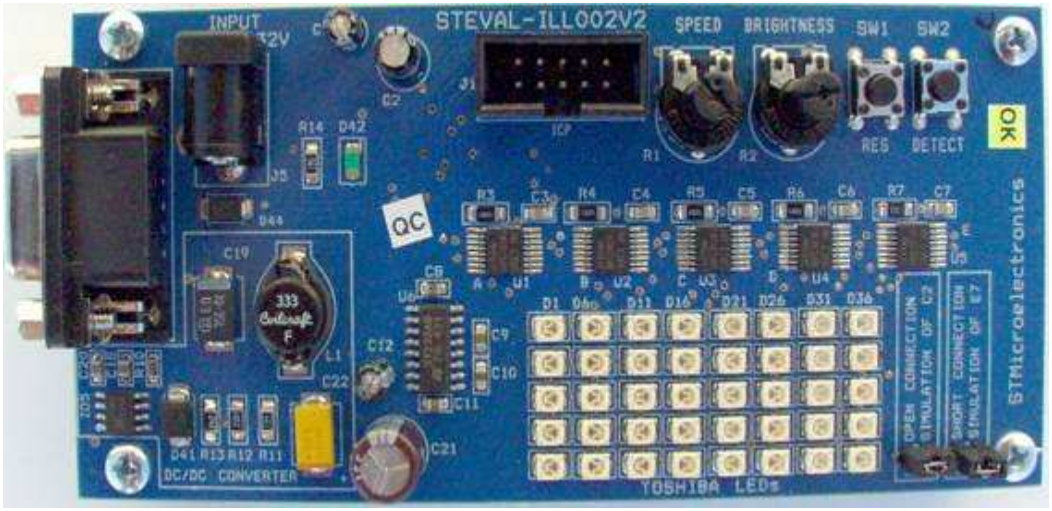
40 LED array evaluation board (with diagnostic) based on advanced logic STP08DP05

Documentation: AN2141, AN2415, AN2478

Vishay LEDs

Features:

- 40 TOSHIBA GREEN LED Matrix is driven
- Open and Short Line error detection
- Adjustable Brightness
- Led current regulation
- Adjustable blinking speed
- Different blinking modes
- Animated text
- DC/DC Pre-regulator for high efficiency



Key Products:
✓ST7FLITE
✓STP08DP05
✓ST232
✓L5970D

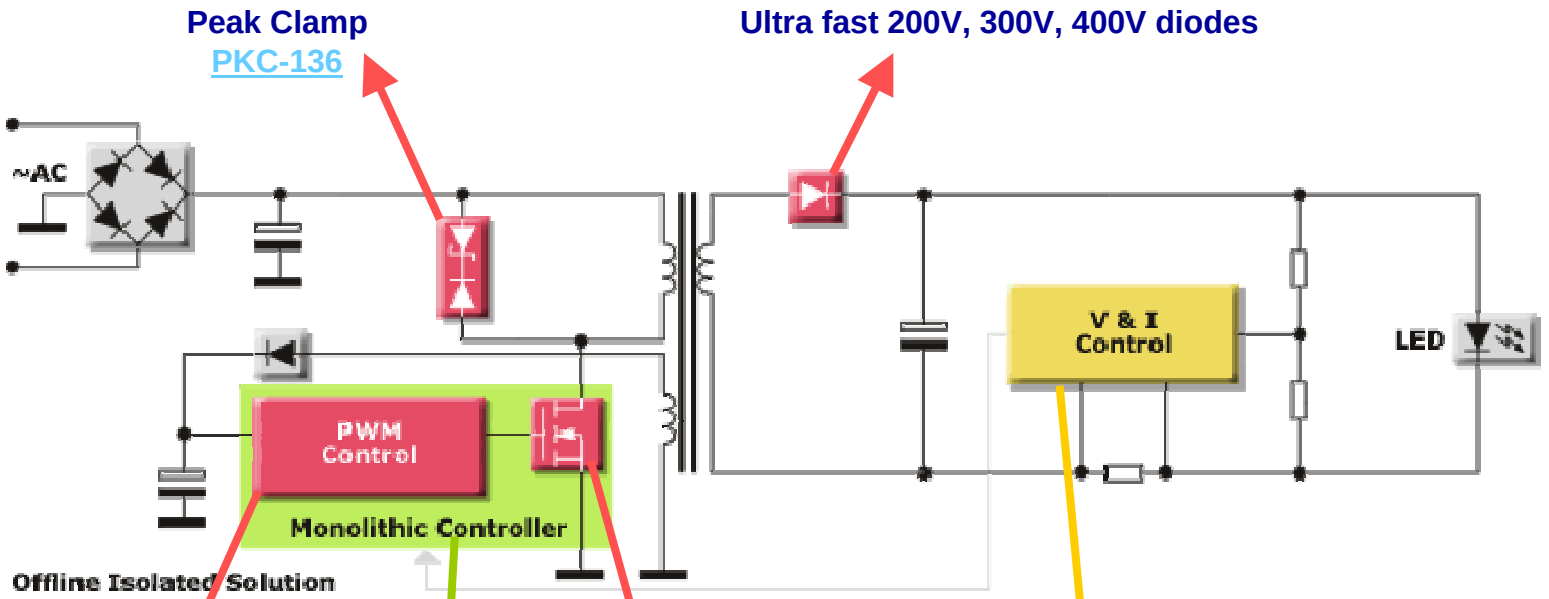
Typical Applications:
✓LED Information Panels
✓LED Displays
✓Traffic Signs
✓Signals
✓Decorative Lighting
✓Home Appliances (White Goods)

STEVAL-ILL002V4

AC/DC single package drivers VIPer+ with minimum stand-by consumption

Offline LED Driver

Illumination, Architectural Lighting, General Lighting



Peak Clamp
PKC-136

Ultra fast 200V, 300V, 400V diodes

Current Mode PWM Controller
Quasi-Resonant Controller

Viper Family
Viper12/22A
Viper17 (+)
Viper27 (+)
Viper53

N-Channel MOSFET

TSM family
TSM101
TSM102
TSM103
TSM104

Application notes

AN1916
AN2042
AN2067
AN2011
AN1059
AN1060

Offline LED Driver

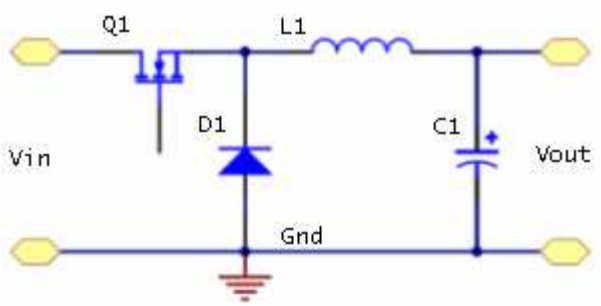
- Illumination
- Architectural & design lighting
- Emergency lighting
- Water features and pools

INPUT	OUTPUT		Main ST-Parts	Remark	Ref Design	App Note
Vin [VAC]	Iout [mA]	Vout [VDC]				
90 to 264	350	3.0 to 15	VIPer12A & TSM103	Insulated output constant current source	STEVAL-ILL005V1	AN1916
90 to 264	350	6.0 to 27	VIPer22 & TSM103	Insulated output constant current source	STEVAL-ILL006V1	AN1916
85 to 135 or 185 to 265	350	3.5 to 28	VIPer22 & TSM104	Insulated output Dimmable current source	STEVAL-ILL001V1	AN2042
176 to 264	500	3.5 - 7(max) *	Viper17 & TSM103W	non-insulated Constant current source	STEVAL-ILL017V1	AN2811
82 to 265	200 to 1000	5 to 40	VIPer53 & TSM101	Insulated output Dimmable current source	Schematic and layout	AN2067
90 to 265	Up to 700	Up to 48	L6562A & TSM1052	Insulated PFC & current source	EVL6562A-35WFLB	AN2838
88 to 265	350 or 700 or 1000	Up to 400VDC	L6562A & HV-Pwr MOSFETs & rectifier	80W LED Driver Non–insulated SMPS: PFC & Modified Buck	STEVAL-ILL013V1	UM0670 (Coming soon)

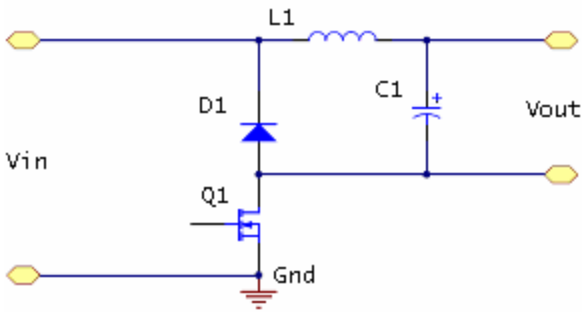
* Limited Vout in STEVAL-ILL017V1, VIPer17 can provide also up to 15V and 350mA

Low Power Offline LED Driver Topologies

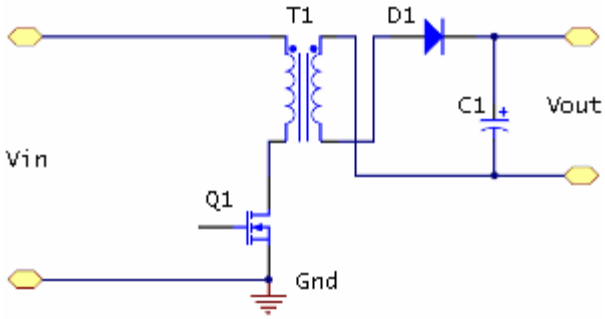
- **Buck converter**
  - Q1 at high side requires a floating gate-drive
  - Inherent L-C filter provides low ripple current
  - Very short duty cycle with big Vin to Vout ratio



- **Modified or inverted buck converter**
  - Q1 at low side, the gate-drive is referred to ground
  - Vout is referred to high side
  - Inherent L-C filter provides low ripple current
  - Very short duty cycle with big Vin to Vout ratio

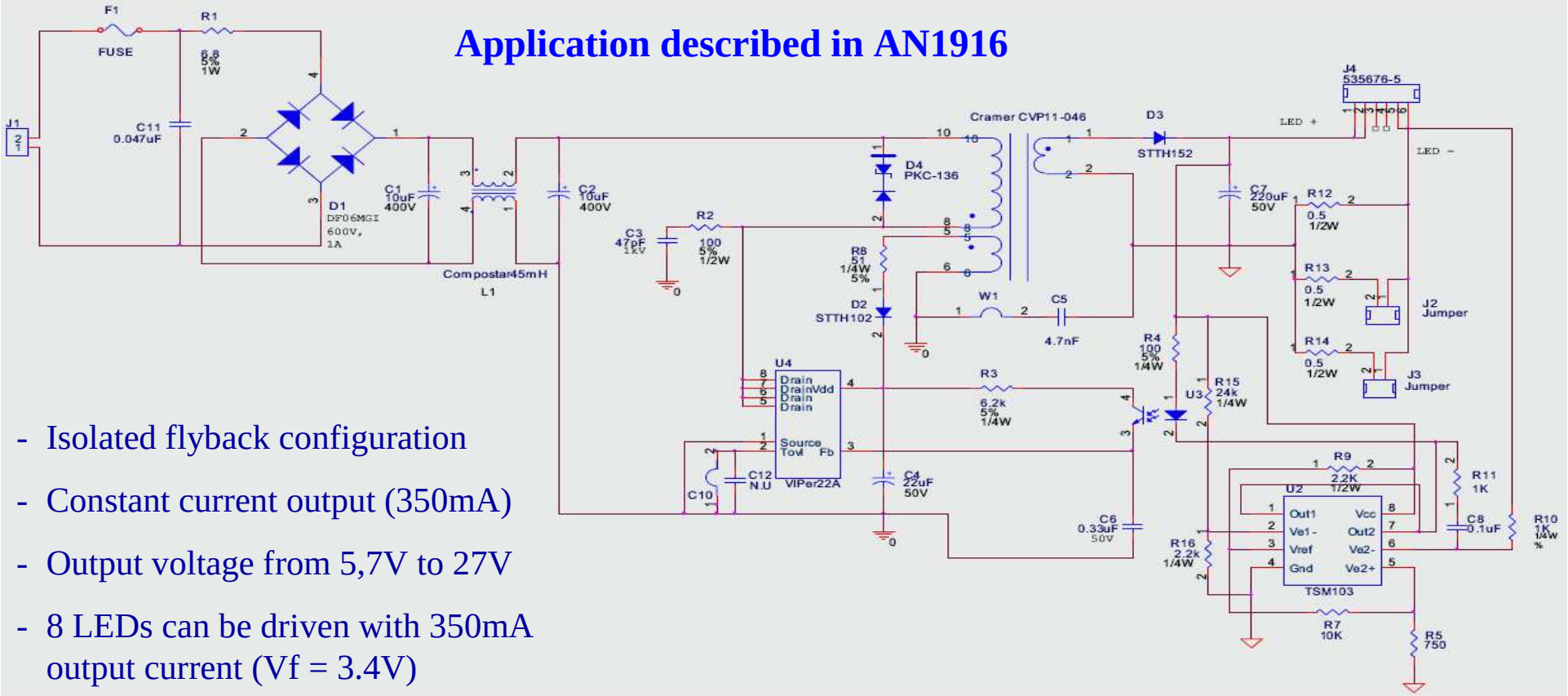


- **Flyback converter**
  - Flyback transformer is required. It also provides bias for Q1 & Vaux for PWM controller
  - Low input current and optimized duty cycle also with big Vin to Vout ratio



VIPer22A Application Example

Application described in AN1916



- Isolated flyback configuration
- Constant current output (350mA)
- Output voltage from 5,7V to 27V
- 8 LEDs can be driven with 350mA output current (Vf = 3.4V)

VIPer22A LED DRIVER					
Vin =90V			Vin =264V		
V diode [V]	Vdd [V]	Iout [mA]	V diode [V]	Vdd [V]	Iout [mA]
5,6	9,2	358	5,7	9,3	358
15,6	24	359	15,6	24	359
19,5	29,5	360	19	29,3	360
22,9	35	360	22,5	34,2	360
25,2	38	360	25,5	38,3	360
27,3	41	361	27,3	41	361

Evaluation Board: STEVAL-ILL006V1

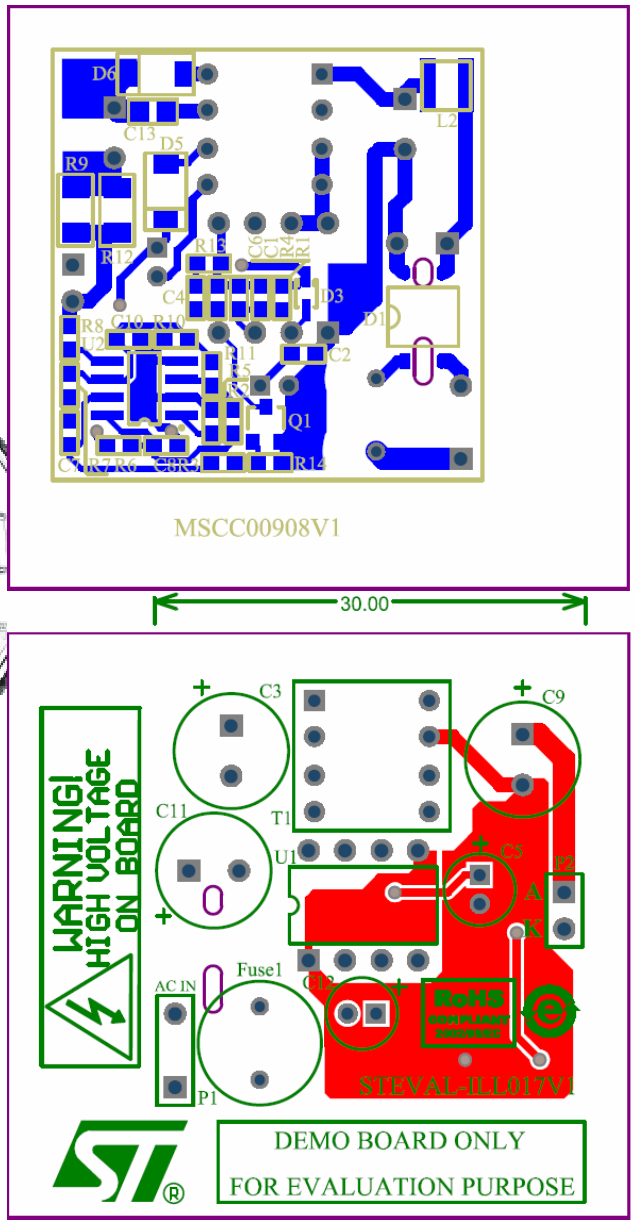
Dimmable Evaluation Board: STEVAL-ILL001V1

STEVAL-ILL017V1 – Reference Design

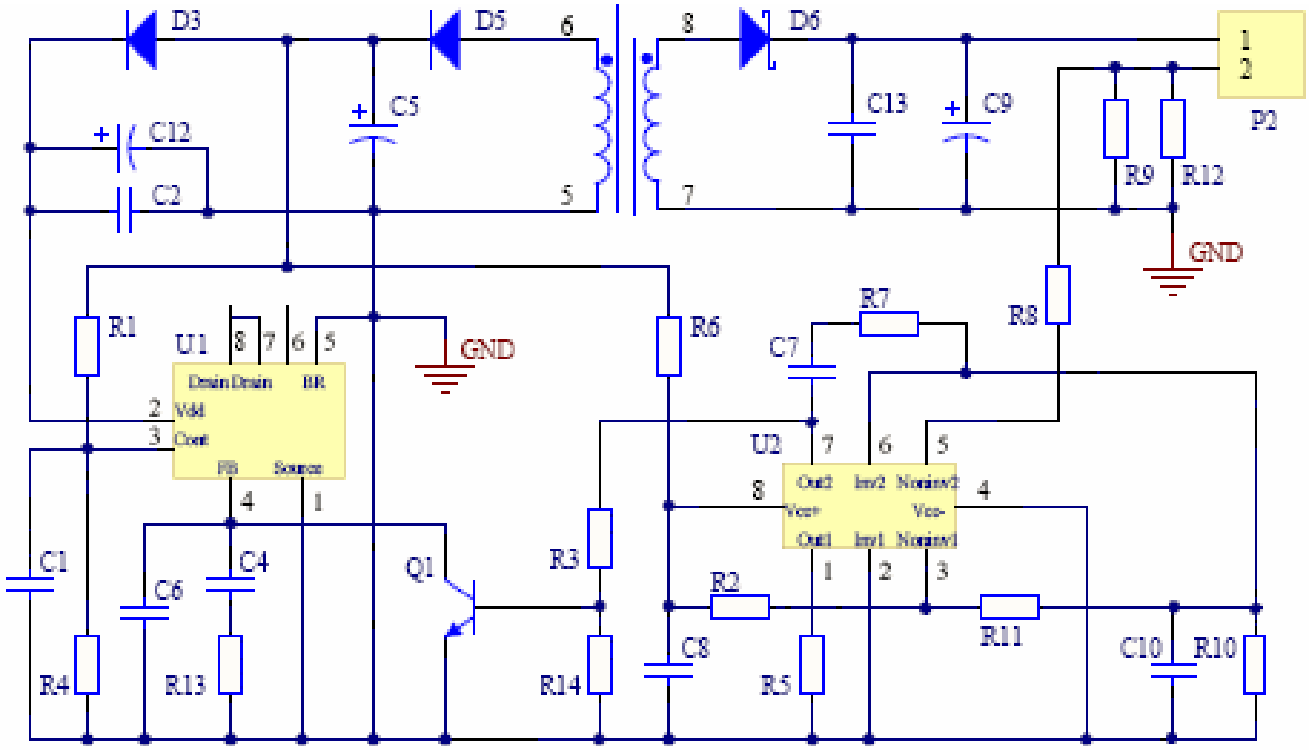
- **2W not-insulated Offline Constant Current LED driver**
  - The PCB dimension is important
  - No line isolation is required
- **The specification is as following**

Parameter	Value
AC input	220 VAC +/- 20%
Output current	500 mA
Output voltage	7 VDC maximum
Dimension	30 mm x 30 mm
Isolation from mains	Not required
Topology	Constant current source

STEVAL-ILL017V1 : Miniature size

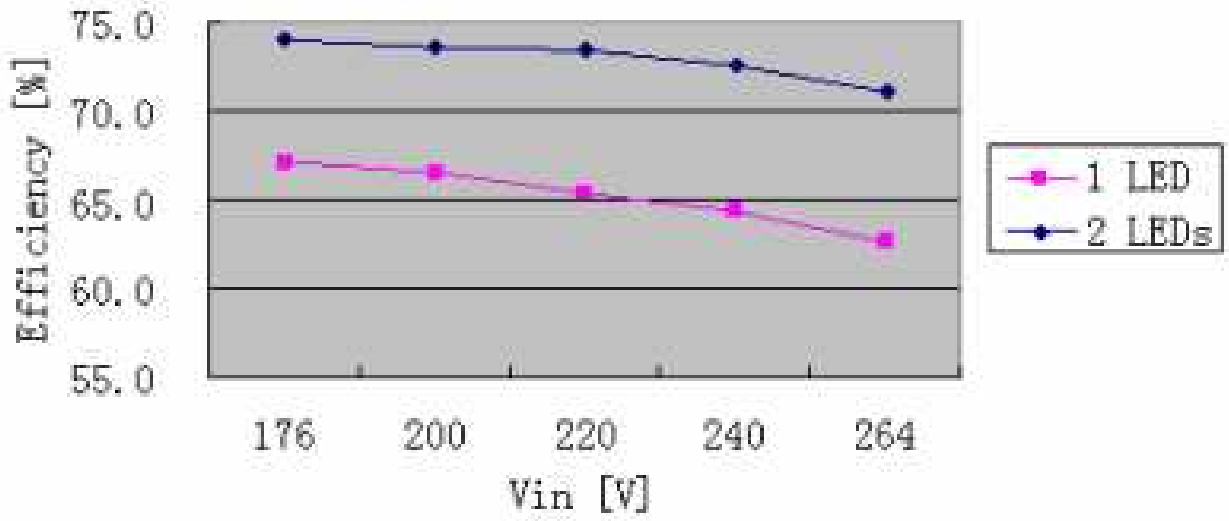


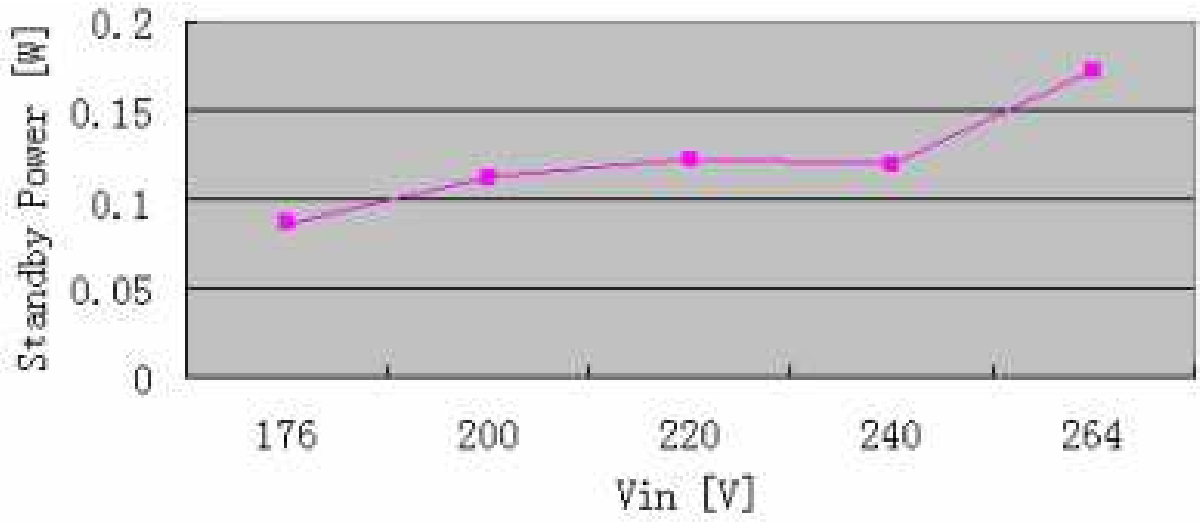
STEVAL-ILL017V1 : Offline Constant Current Control



- **Not isolated (common ground)**
- **R9 &R12, the output-current sensing resistor**
- **R7 & C7 compensation circuit of U2 in order to drive Q1 properly**
- **Bridge R10 & R11 to provide 0.3V reference from Vref in pin 3 of U2**
- **Q1 the buffer stage to feed signal to U1**

STEVAL-ILL017V1 : Load efficiency and stdby power



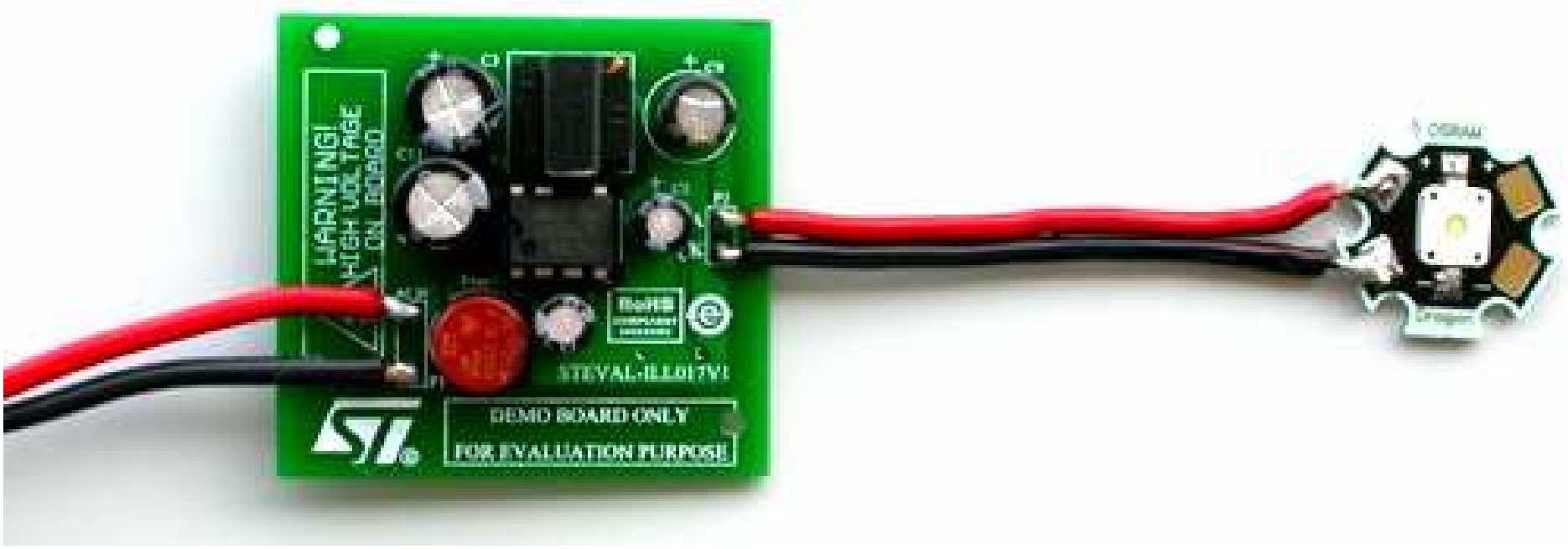


ST Products and technical document

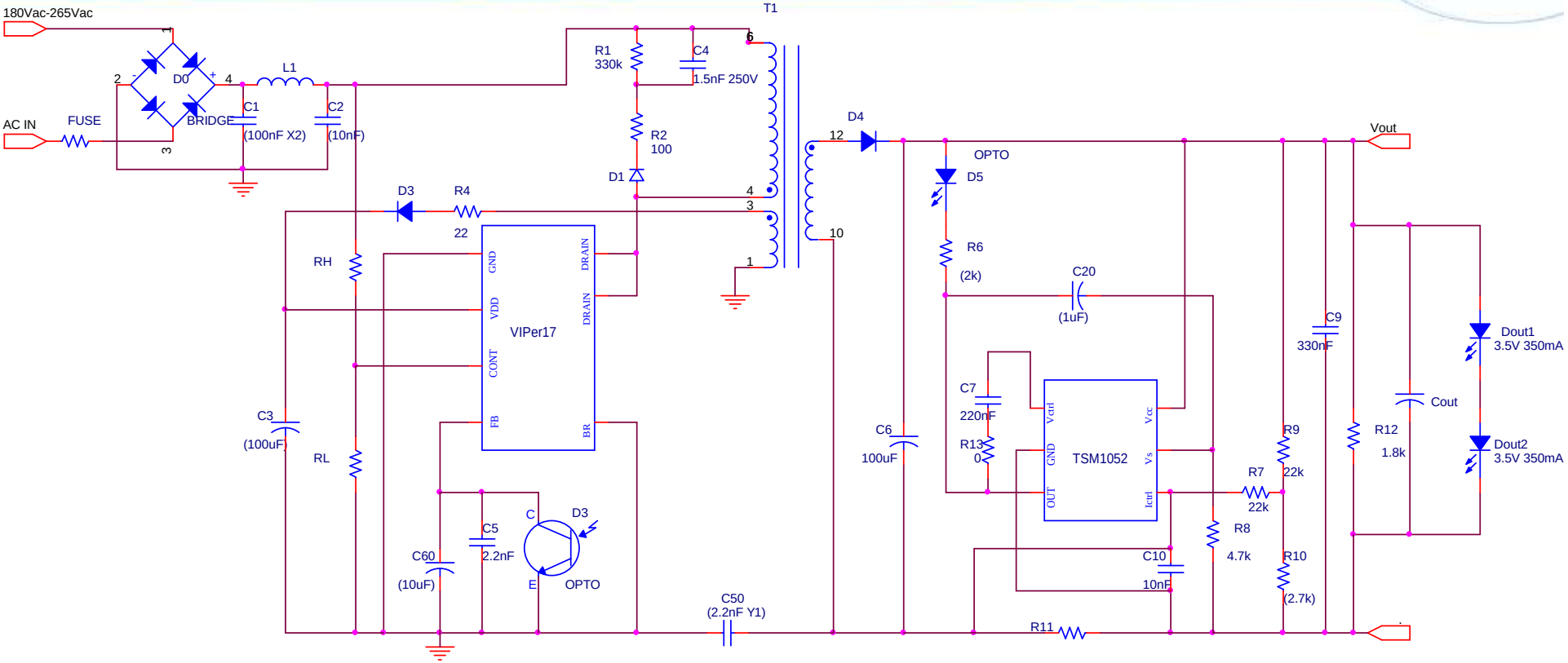
- **VIPER17HN**
  - Offline high voltage converter (115 KHz)
- **TSM103W**
  - Dual operational amplifier and voltage reference
- **STPS2H100A**
  - Power Schottky rectifier
- **STTH1R06A**
  - Turbo 2 ultrafast high voltage rectifier
- **BAT46JFILM**
  - Small signal Schottky diode
- **AN2811**
  - Application note of STEVAL-ILL017V1

More application fields

- **Applicable fields**
  - Fridge / Refrigerator
  - Night light for indoor use
  - Guiding indicator



Insulated Flyback solution with High PF (1)



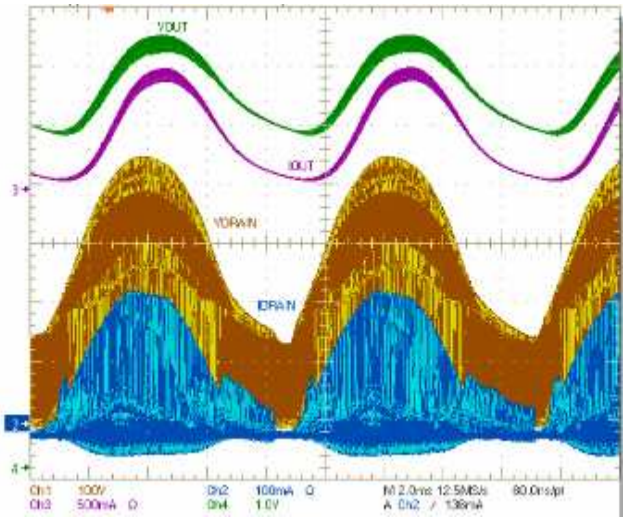
-R11=0.53Ω ⇨ 377mA (typ.)
-RH=1.43MΩ
-RL = 3.3KΩ
-Cout=570µF
-Cin = 10nF

Concept is based on the capability of modulating the Input Current according the mains voltage; it is done thanks to the Viper Current limit internal circuit and to the external resistor divider composed by RH and RL connected between the input, CONT pin and ground.
Input capacitor, C2, is ceramic and only 10 nF.

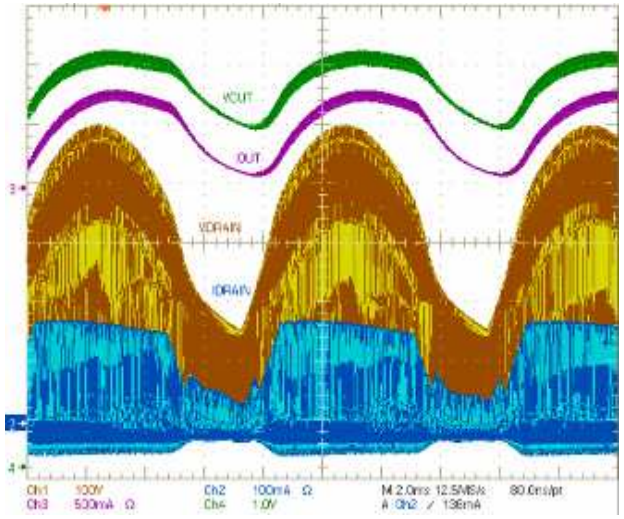
Insulated Flyback solution with High PF (2)

The three figures show input and output voltage and current obtained from the schematic described in the previous page used to supply <u>3x1 W</u> series Led.

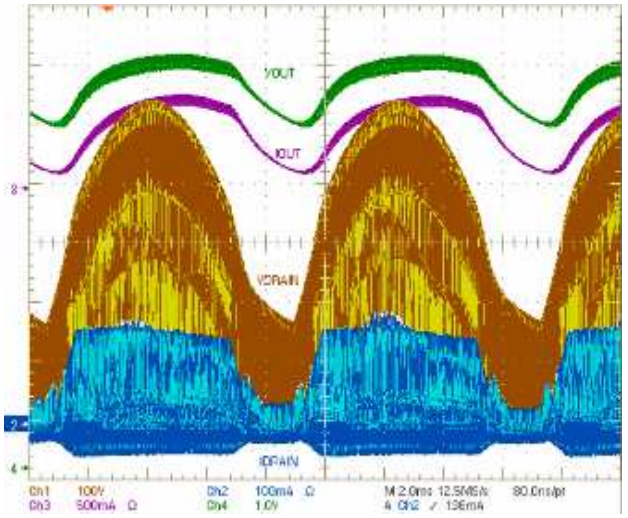
Vin = 180 Vac
PF = 0.944

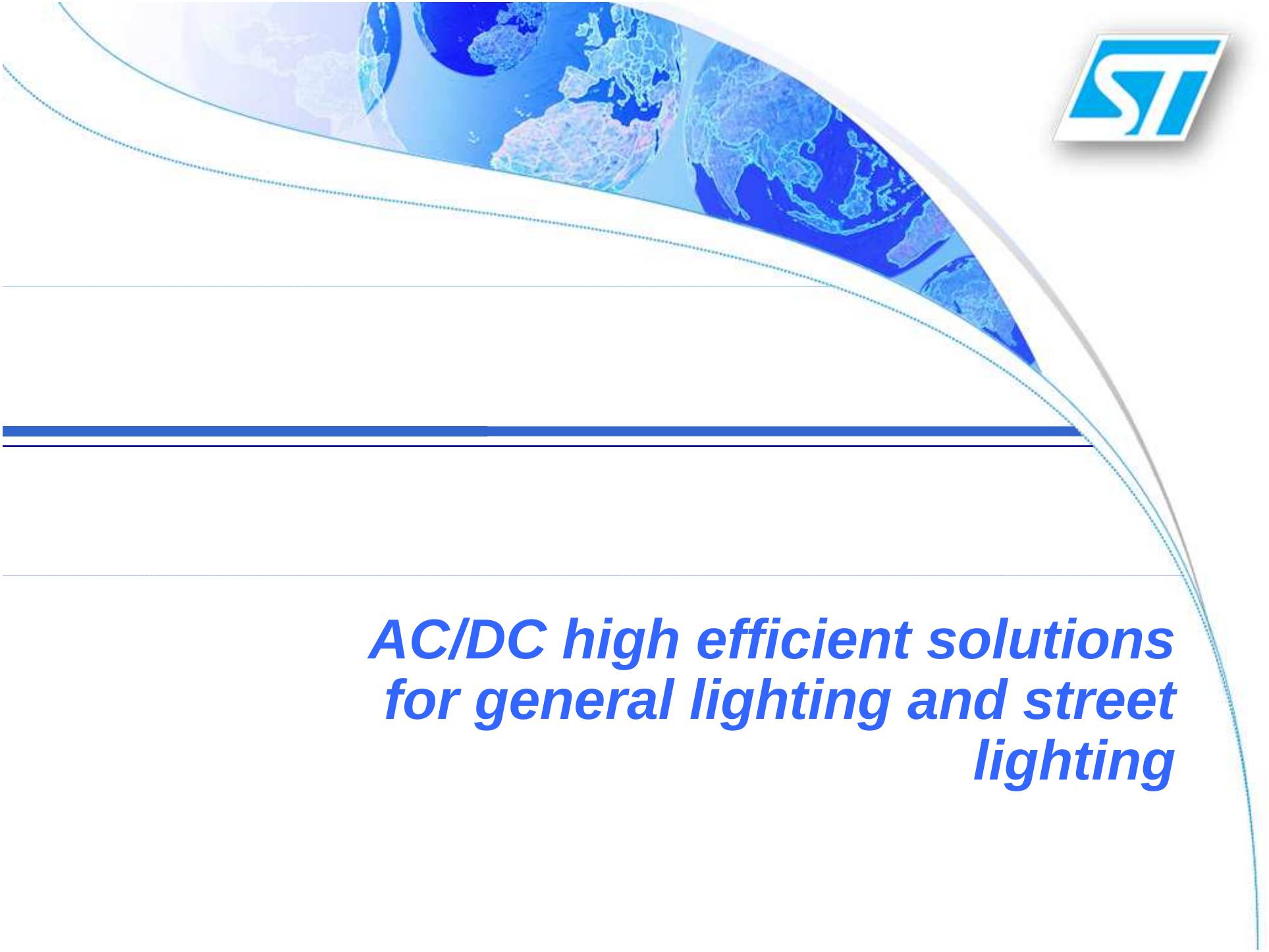


Vin = 230 Vac
PF = 0.917



Vin = 265 Vac
PF = 0.882

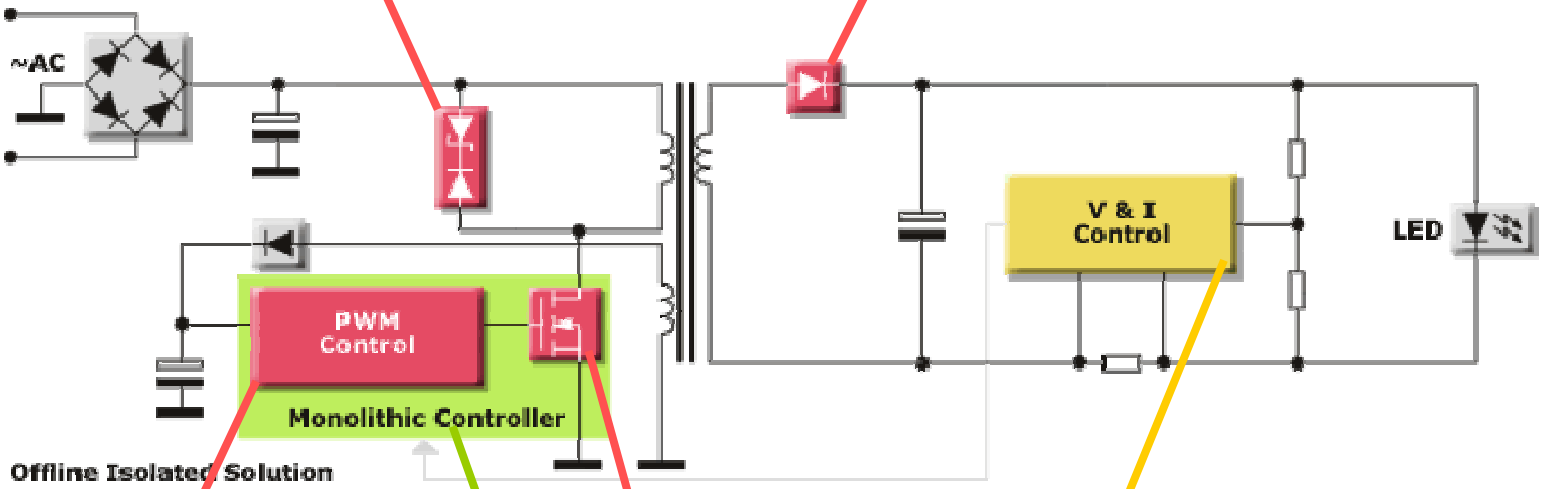




AC/DC high efficient solutions for general lighting and street lighting

Offline LED Driver (Non-/Isolated)

Illumination, Architectural Lighting, General Lighting



Peak Clamp
PKC-136

Ultra fast 200V, 300V, 400V diodes

Current Mode PWM Controller
Quasi-Resonant, TM PFC Controller
Resonant Controller

N-Channel MOSFET

Viper Family
Viper12A
Viper22A
Viper53
Viper17

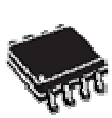
TSM family
TSM101
TSM102
TSM103
TSM104

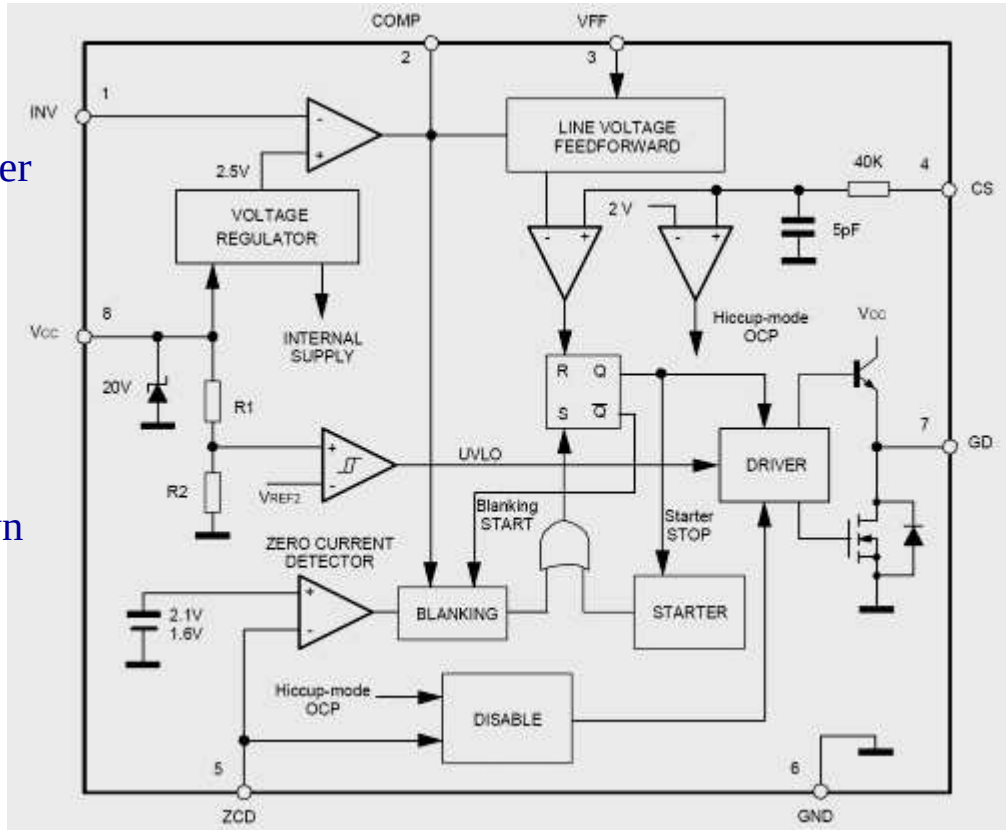
Application notes

AN2838
UM0670

L6565
Quasi Resonant Controller

- Current mode quasi resonant PWM controller
- Micropower start-up current (< 75 uA)
- Low quiescent current (3 mA typ.)
- ZCD input for QR operation
- Frequency foldback function
- Line voltage feedforward function
- Pulse-by-pulse overcurrent protection
- 2nd overcurrent level with latched shutdown
- Disable function
- Internal current sense RC filter
- Package: SO-8 / Minidip8

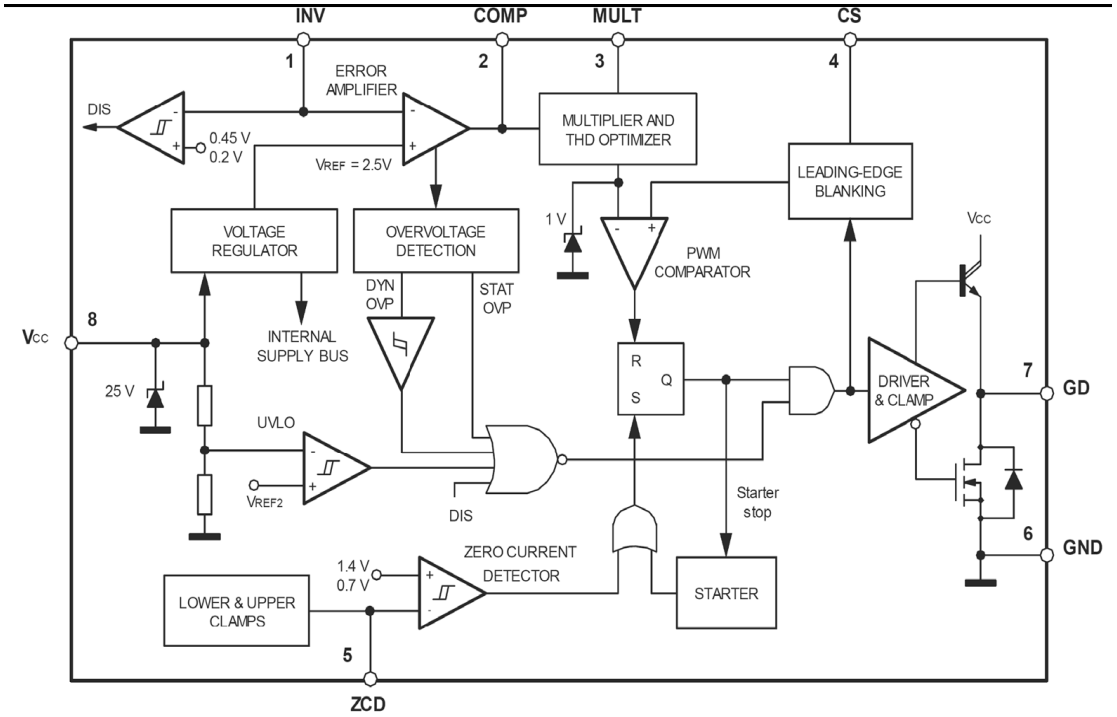




For LED application it is used as a standard fly-back converter with current regulator on the secondary side (e.g. with TSM10xW)

L6562AT PFC Controller

- Guaranteed for extreme temp range (outdoor – Streetlighting)
- Transition-Mode controller of PFC
- Proprietary Multiplier for min THD
- Micropower start-up current (< 30 uA)
- Low quiescent current (2.5 mA typ.)
- ZCD inputfor TM operation
- Very precise adjustable output OVP
- 1% internal reference
- On Chip Filter on current sense
- Pulse-by-pulse overcurrent protection
- Disable function
- Internal current sense RC filter
- Package: SO-8 / Minidip8



For LED application it is used as a standard fly-back converter with

current regulator on the secondary side (e.g. with TSM10xW)

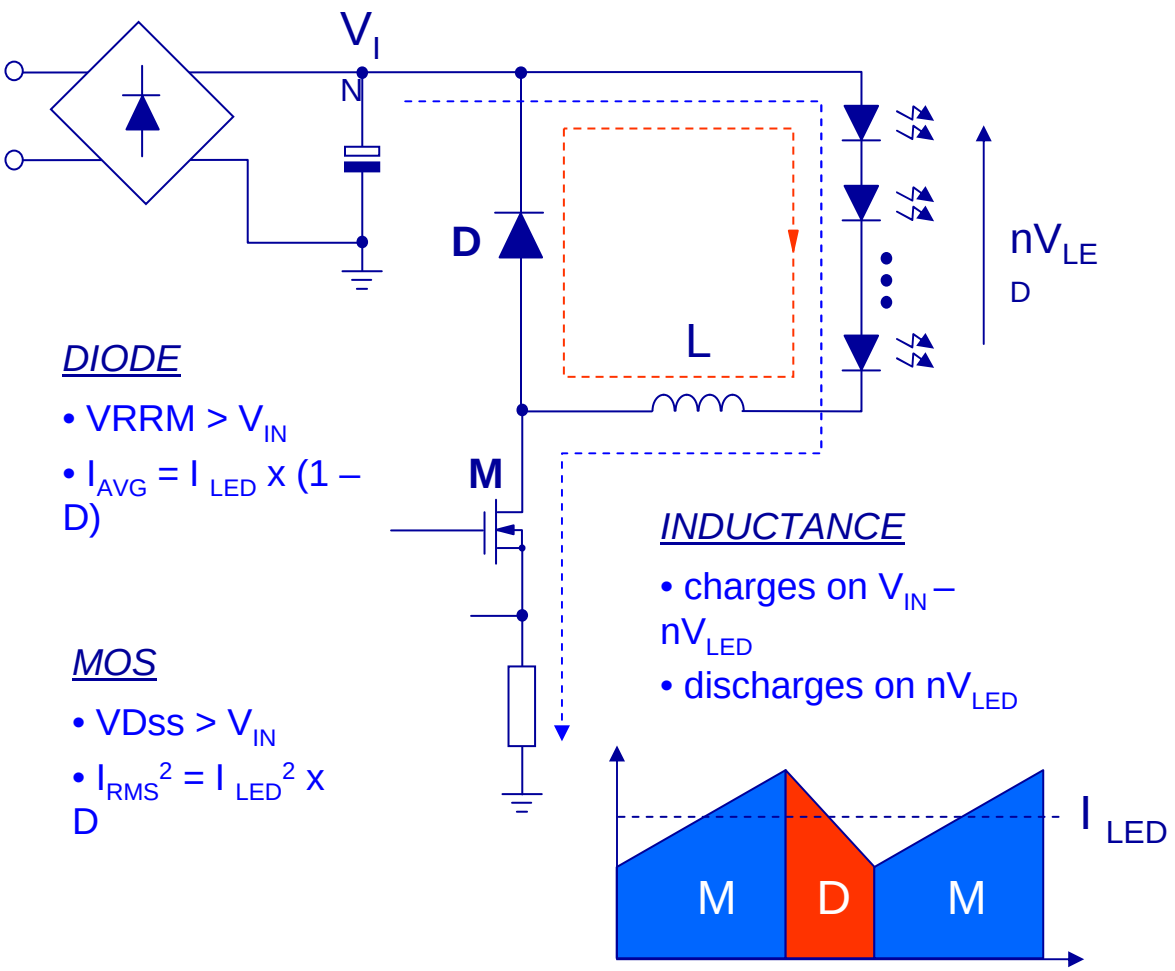
L656x Application

Modified Non-Isolated Buck Controller for LED Supply

Modified buck (step-down)

- Suitable for applications
  - not isolated
  - not requiring PF

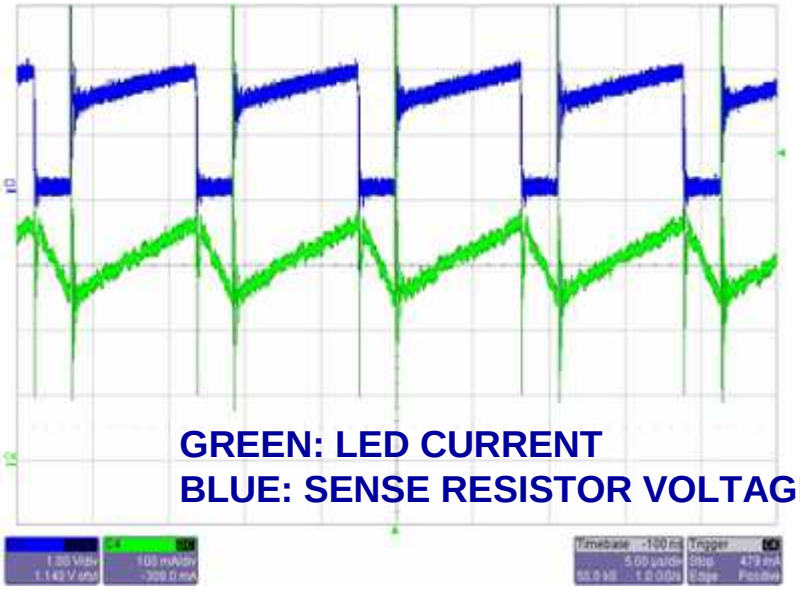
  e.g. emercency light, trafficlight...
- MOS referred to ground and not to V_{IN} (low voltage driver)
- Open loop operation (frequency accuracy required)
- Working range: $nV_{LED} < V_{IN(MIN)}$
- $D = nV_{LED} / V_{IN}$



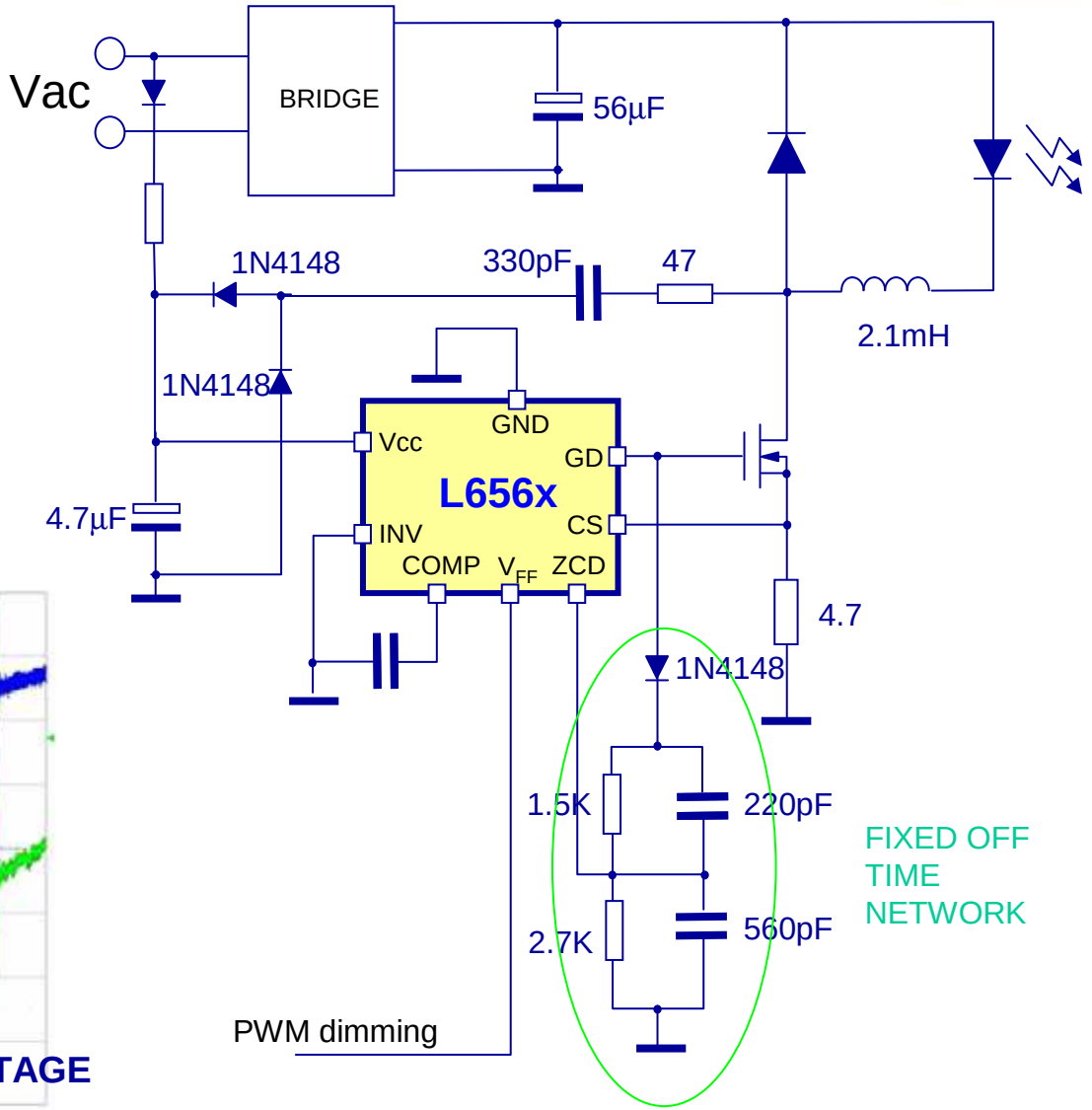
L656x Application

Modified Non-Isolated Buck Controller for LED Supply

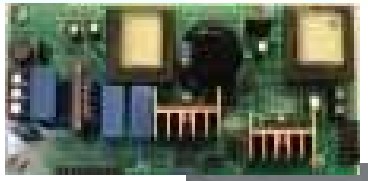
- Flexible Number of LEDs IN SERIES (eg. 30 x 1W GOLDEN DRAGON)
- E.g. Vin = 110Vac or 230V
- Measured efficiency ~ 90% (but application fine tuning is still necessary, e.g. MOS, DIODE)



GREEN: LED CURRENT
BLUE: SENSE RESISTOR VOLTAGE



Non-Insulated Offline LED Driver for Fashionable Lighting (1/2)



Input:

- Active PFC
- Wide input voltage range (88 – 264V

Output:

- Current source 350, 700mA, 1000m adjustable mean value
- Output power 80W
- Max current ripple ±100mA
- Dimmable 0 – 100%

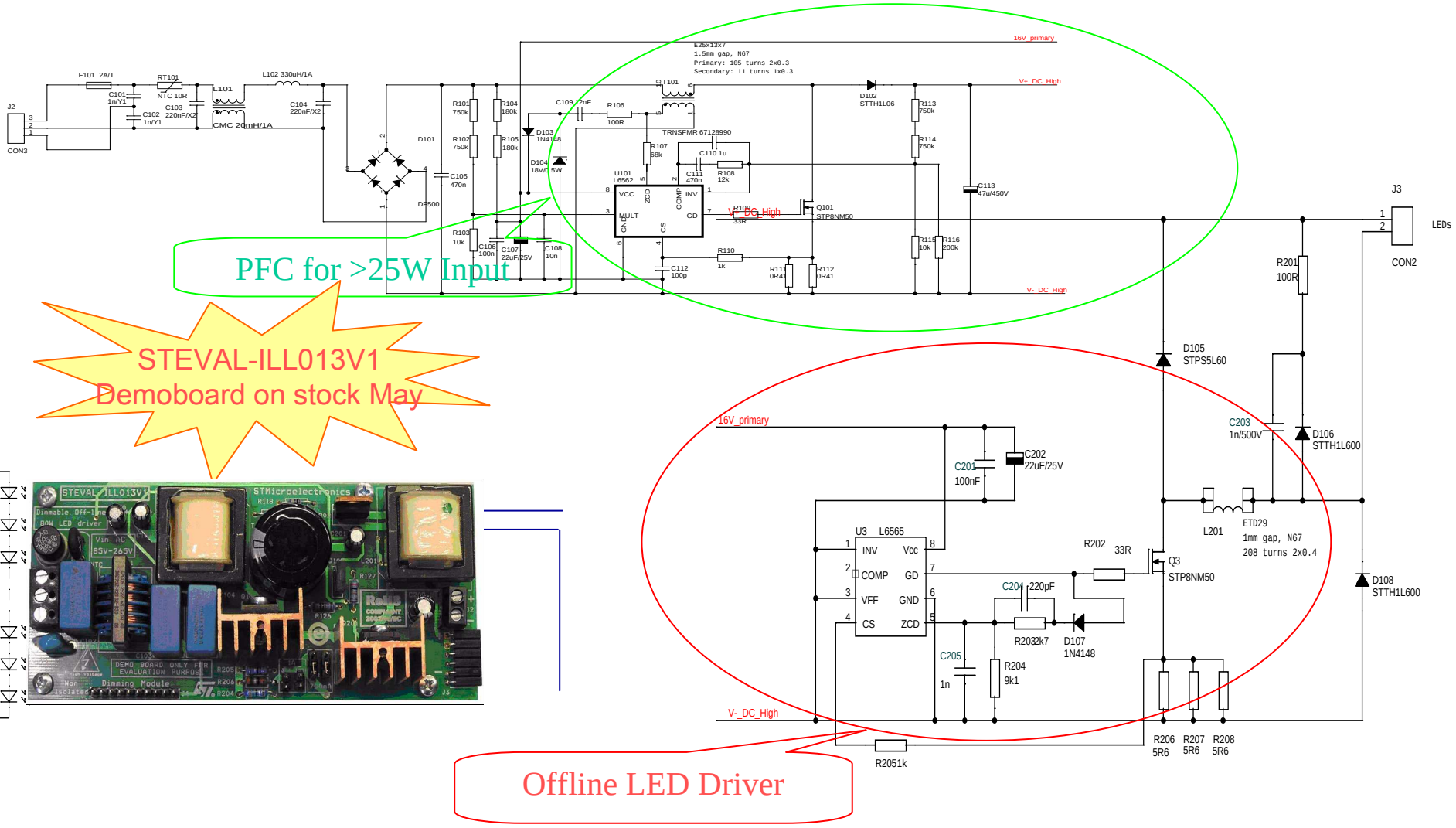
Dimension

- 60 x 130 x 27 mm

Efficiency (prototype)

- ~90%

Non-Insulated Offline LED Driver for Fashionable Lighting (2/2)



L6562A Insulated High PF AC/DC LEDs Driver 35W

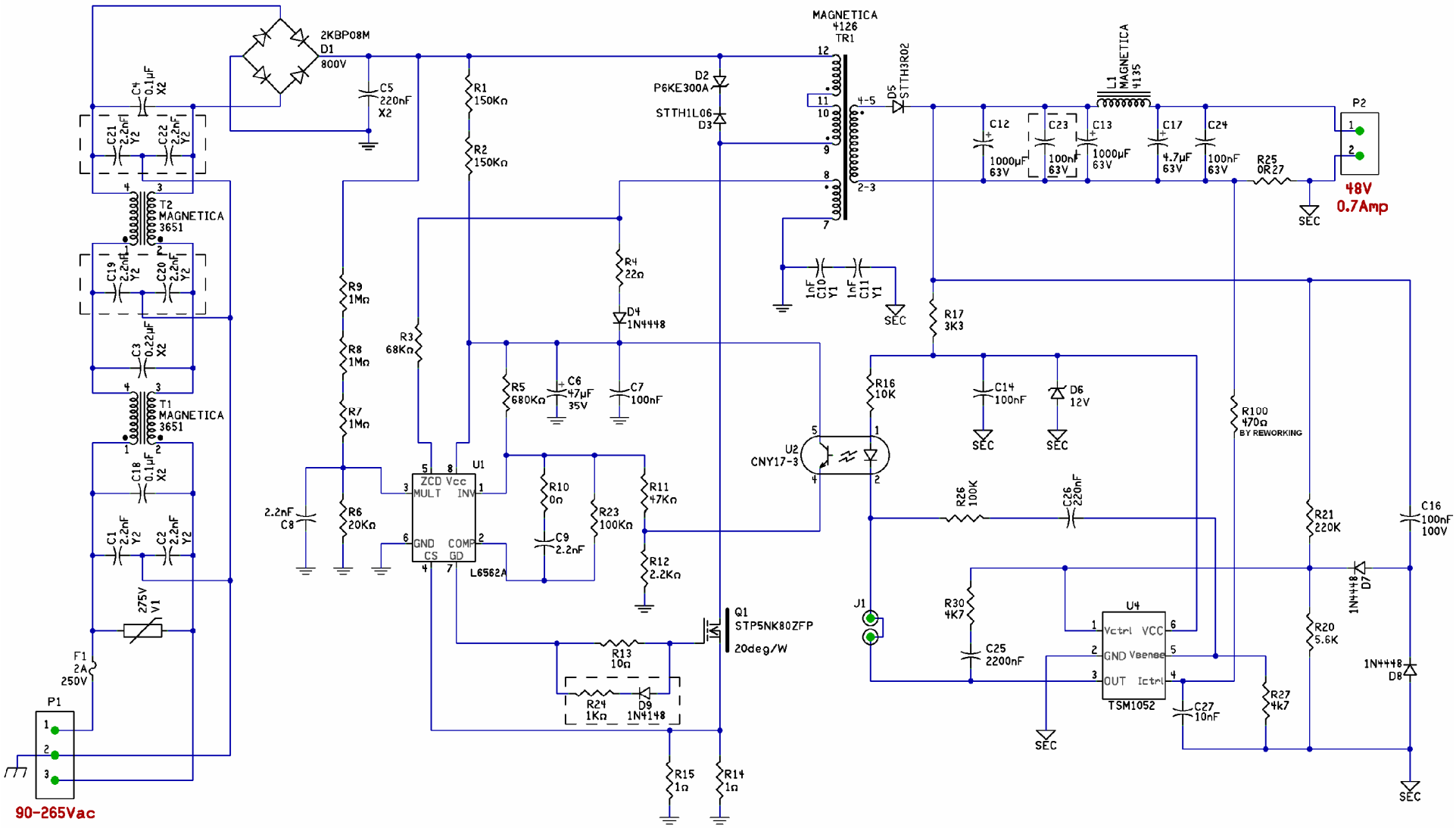
EVL6562A-35WFLB

AN2838

New

- Line voltage range: 90 to 265 Vac
- Minimum Line frequency (f_L): 47-63 Hz
- Regulated output voltage: 48V
- Rated output power: 35 W
- Power Factor (Load ≥ 50%): 0.9 minimum
- Minimum efficiency: 85% at full load
- Maximum $2f_L$ output voltage ripple: 1.5V pk-pk / 0.39 Vrms (@Vin=90Vac, Pout=35W)
- Maximum ambient temperature: 50 °C
- Conducted EMI: In acc. with EN55022 Class-B
- Surge rejection: Surge Test 2.5kV
- Primary to secondary insulation: 4 kV
- PCB type and size: Double Side, 35 um, FR-4, 120 x 82 mm

L6562A Insulated High PF AC/DC LEDs Driver 35W



L6562A Insulated High PF AC/DC LEDs Driver 35W

- *L6562A in fly-back topology addresses medium power LED applications offering :*
  - ***Cheap and flexible Insulated Single Stage conversion***
  - ***PF greater than 0.9***
  - ***NO electrolytic input capacitor***
  - ***NO electrolytic output capacitor if its value allows the use of ceramics***
- *Key Components:*
  - ***L6562A(T), TSM1052, STP5NK80ZFP, STTH1L06, STTH3R02***
- *Tools:*
  - ***EVL6562A-35WFLB (voltage output can be expanded to Curr Ctrl)***
  - ***AN2838***

Topologies & Solutions for Street Lighting

New trend for High power Street lights is based on LEDs due to :

- **reliable and safe**
- **technically advanced**
- **economical**
- **environmentally friendly**
- **convenient for maintenance**
- **save energy**
- **improve light quality**

Comparison Lighting Quality with LED and HPS lamps

Street lighting with 108W LED lamp

Street lighting with 250W HPS lamp

Source: Osram Opto Semiconductor

Comparison Lighting Quality with LED and HPS lamps

LEDs Street Light

Current solutions in the market are facing some main bottlenecks:

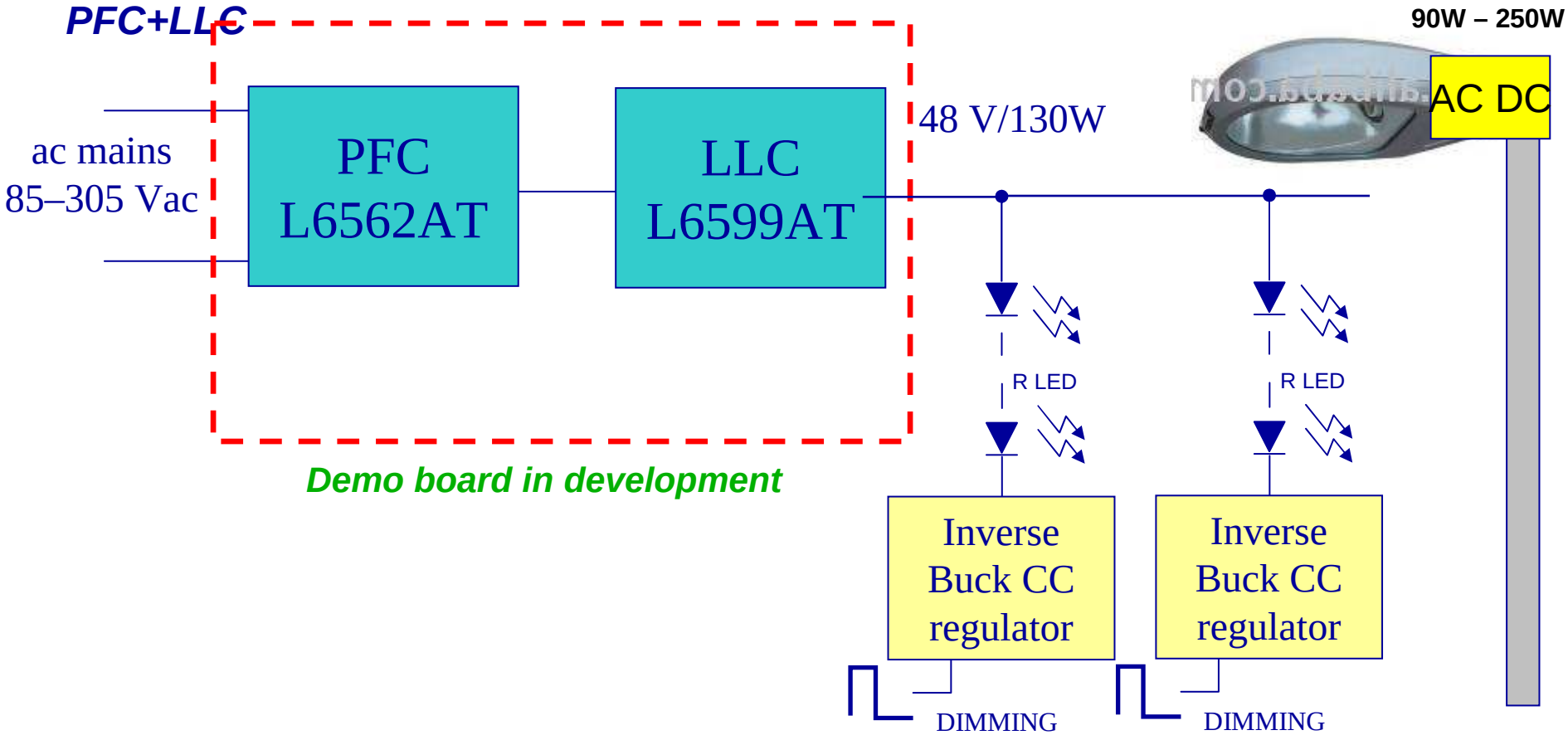
- **Life time of the solution**: after 1.5 years a lot of failures in LED and power supplies. One of the most critical components in the power supply is the **E-CAP**.

- **Wide range of temperature operation**: still a lot of problems in sustaining adverse weather operating conditions and power dissipation

- **Market maturity**: This business has a very high potential but it is still in the demand creation phase and waiting for the adoption form local governments.

LED Street Light : ST solution

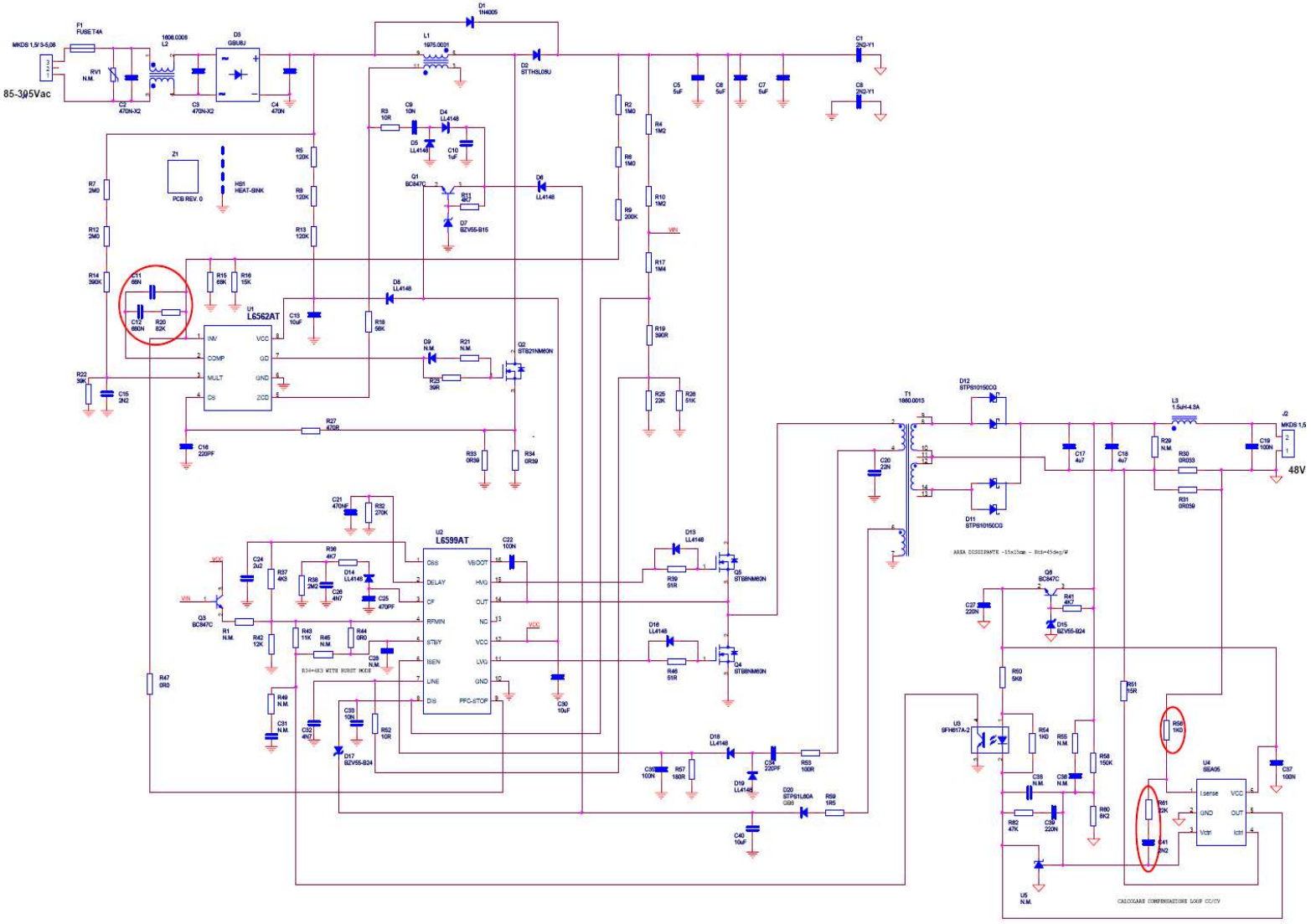
ST addresses all these bottlenecks with a solution based on PFC+LLC



Demo board in development

L6562AT ***and*** *L6599AT* ***are guaranteed over -40 to +125 degrees making them suitable for reliable power supply with very aggressive form factor easily fitting all the current street lamp solutions.***

Schematic of Streetlighting PFC + Resonant Circuit



Suitable for 120W Streetlighting, sizeable to 250W

Streetlighting PFC + Resonant Circuit

- **Key components:**
  - PFC L6562AT
  - Resonant Controller L6599AT
  - MOSFETs: STP21NM50N, STP8NM60N
  - Ultrafast Diode: STTH3L06U
  - Schottky Diodes: STPS1015DCG
- **Tools:**
  - Reference board in design
  - AN in preparation

Switching DC/DC up to 2.8A supply and control for general lighting and automotive

Low Voltage LED-Driver

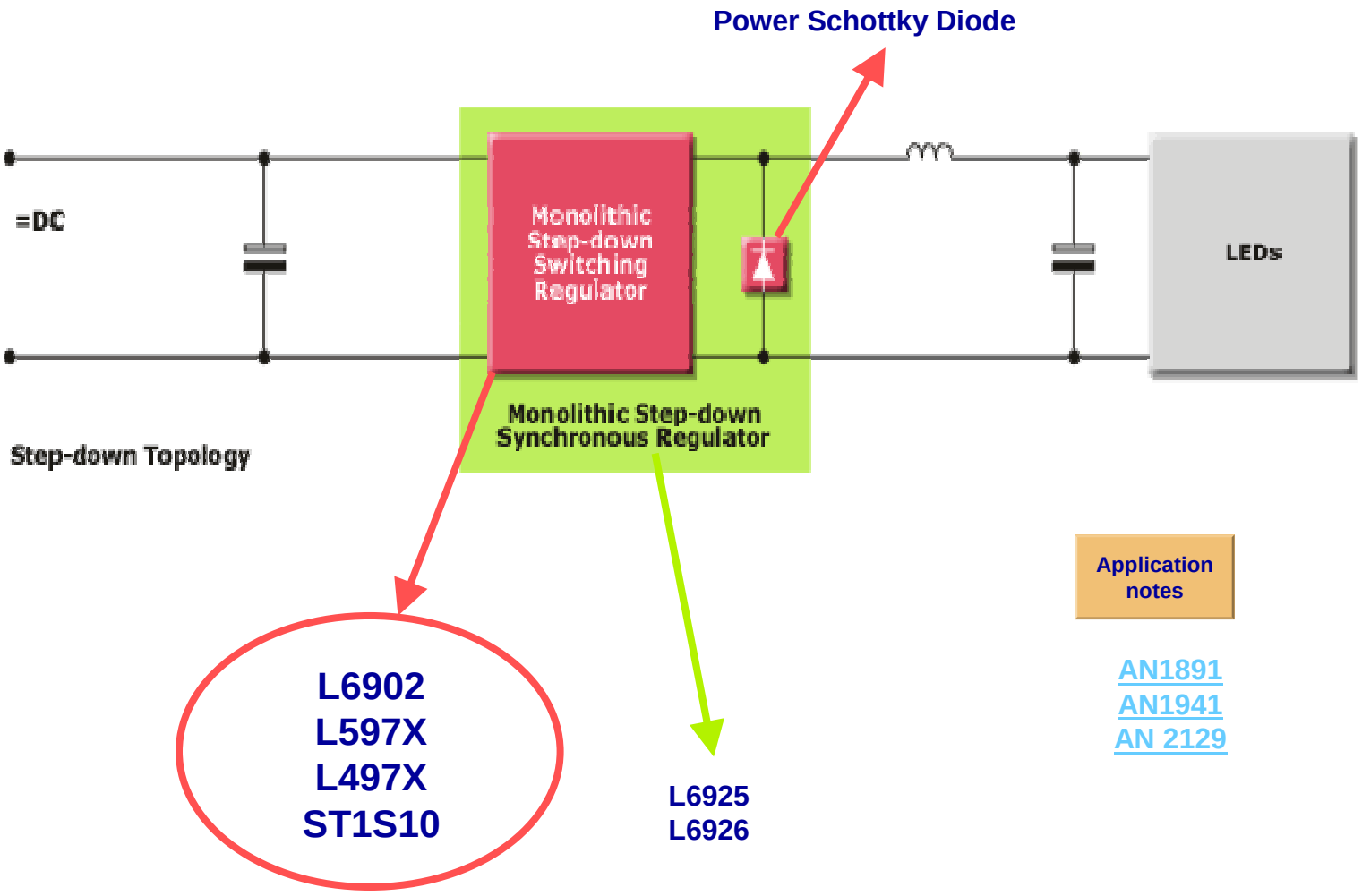
Where **Vin < V(LED)** use **Step Up** topology*. Where **Vin > V(LED)** use **Step Down** topology*.

Input	Output		ST-Part	Remark	Ref Design	App Note
Vin [VDC]	Vout [VDC]	Iout [mA]				
Step Up						
2.5 to 5.0 3.5 to 5.0	Up to 18.5 Up to 37.0	20 40	STLD20D STLD40D	Step up current control	STEVAL-TLL001V1	AN2333
0.6 to 5.5	2 to 5.2	500	L6920	Step up current control	STEVAL-ILL008V1	AN1891, AN1941
4.5 to 36	Up to 36	6 X 30 6 X 85	LED7706 LED7707	1 x Step up ; 6 x linear current sink, dimmable	EVALED7706 EVALED7707	AN2806
Step Down						
8.0 to 18	2.5 to 14	1000-2800	L6726+ STS8DNH3LL	Step down current control dimmable	STEVAL-ILL023V1	In preparation
8.0 to 36	1.235 to 34	1000	L6902	Step down current control dimmable	STEVAL-ILL010V1	AN1891, AN1941, AN2129
4.4 to 36	1.2 to 35	2500	L5973	Step down current control	STEVAL-ILL007V1	AN2259
8.0 to 55	3.3 to 50	1000	L4976	Step down current control		AN1891
e.g. 100	<Vin	e.g. 700	L6562 + PowerMOS	Modified Buck. Vin; Vout; Iout depend on PowerMOS mainly	Schematics available	
Linear current source						
4.5 to 40	4.5 to 40	500 1500 2000	STCS05 STCS1 STCS2	Linear constant current source. PWM dimming up to 50kHz	STEVAL-ILL014V1	UM0422

* for buck/boost ref. AN1891 and AN1518

Step-down topology

Signage, Torch, portable lighting



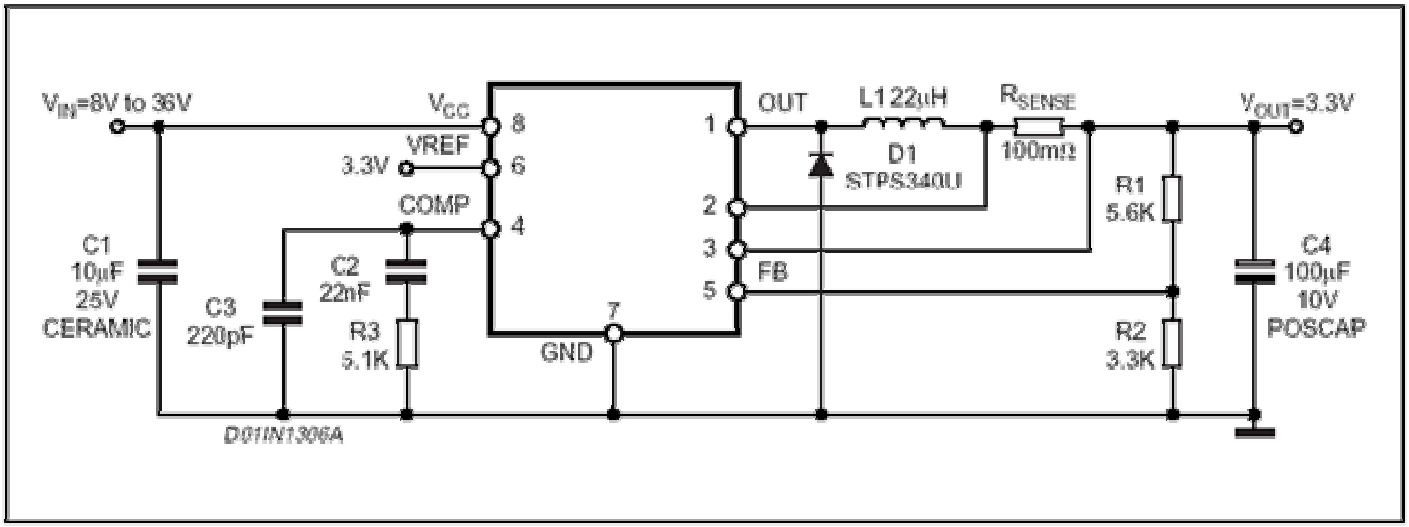
Application notes

AN1891
AN1941
AN 2129

L6902D and Automotive A6902
Up to 1A switching regulator, with adjustable current limit

- Step-down switching regulator
- Up to 1A output current
- 5% output current accuracy
- Adjustable current limit
- Thermal shutdown
- 250KHz internally fixed frequency
- Precise 3.3V (±2%) reference voltage
- Operating input voltage from 8V to 36V
- Output voltage adjustable from 1.235V to 34V
- Protection against feedback disconnection

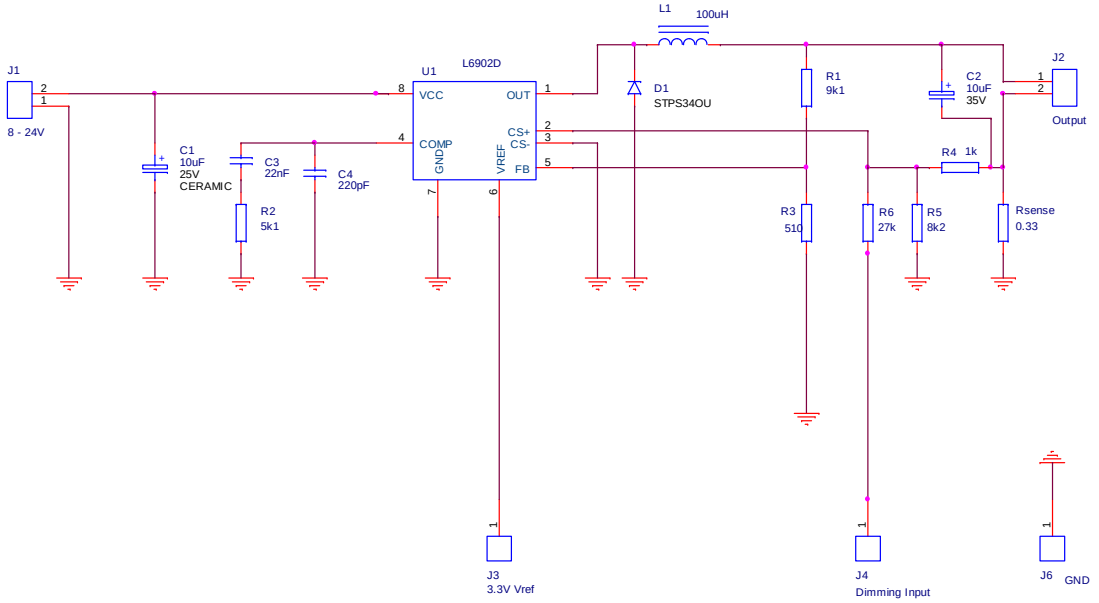
TEST AND APPLICATION CIRCUIT



STEVAL-ILL010V1 - L6902D Reference Design

- **Designed for 350mA LEDs**
- **Easily modification for higher current**
- **Fully dimmable board**
- **Analog dimming**
- **Digital (PWM) dimming**
- **Maximum output voltage limited**
- **5 LEDs can be driven with 700mA output current (Vf = 4.4V)**
- **6 LEDs can be driven with 350mA output current (Vf = 4V)**

- **Reference Documentation : AN 2129**



More LED applications in **AN 1891**, **AN 1941**

L597x Family
Step down switching regulator

- 4.4V to 36V input voltage
- Internal P-channel DMOS transistor (with a typical Rds on of 250mΩ).
- adjustable output from 1.25V
- 250kHz or 500kHz internally fixed frequency
- 3.3V reference available (L5972D)
- Inhibit for zero current consumption (except L5972D)
- Internal current limiting
- Protection against feedback disconnection
- Thermal shutdown and Synchronization

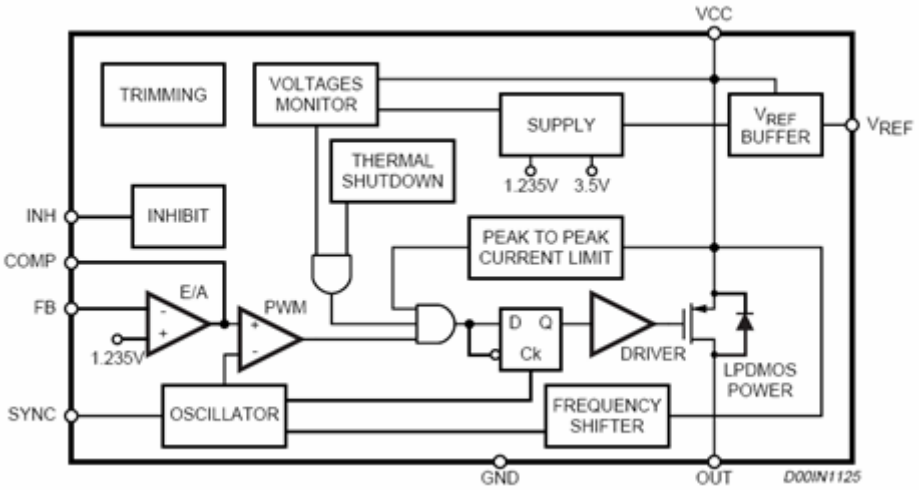
L5970D
1A switch in SO8

L5970AD
1A Switch in SO8
500kHz switching frequency

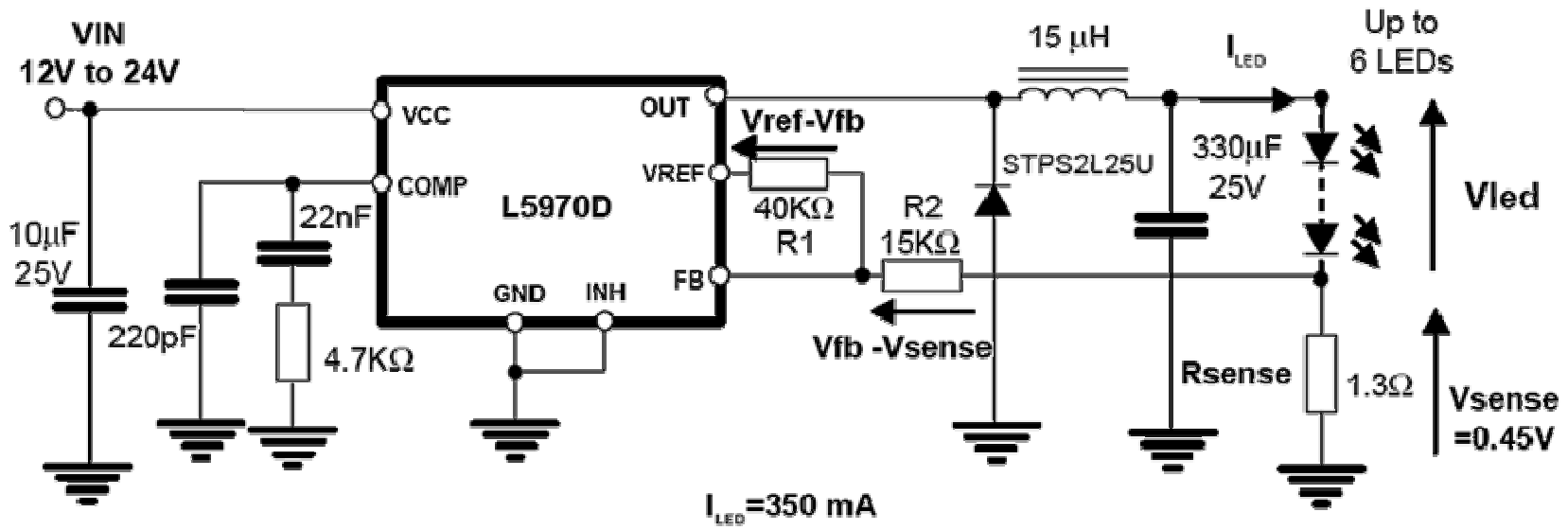
L5972D
2A switch in SO8 (4 ground leads)

L5973D
2.5A switch in HSO8

L5973AD
2A switch in HSO8
500kHz switching frequency



L597x Application Schematic

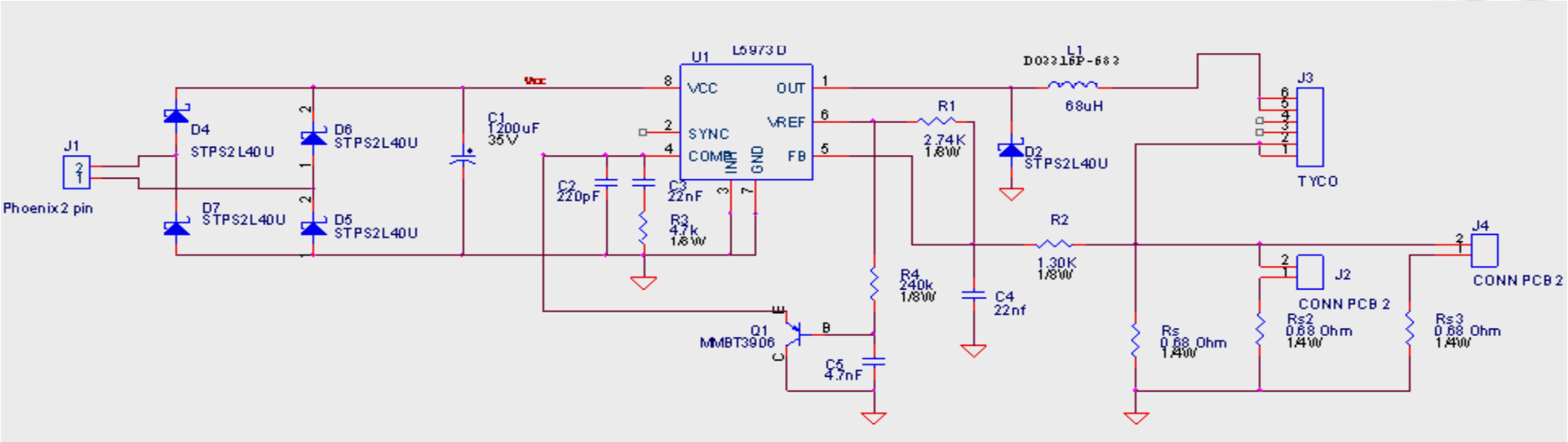


Circuit for driving up to 6 LEDs

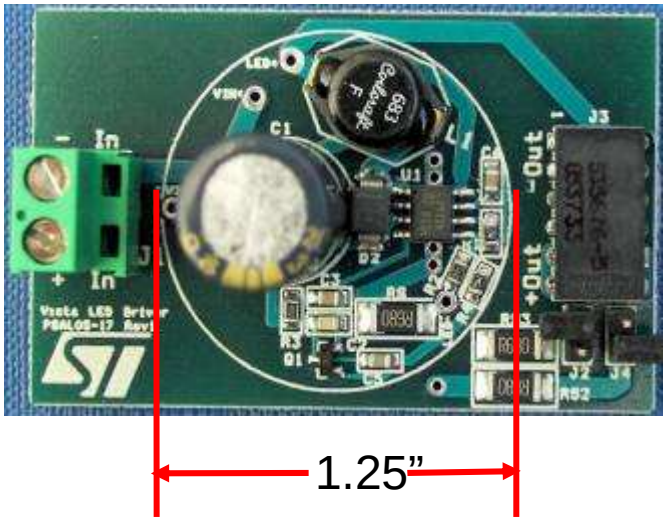
Efficiency	1 LED	2 LEDs	3 LEDS	4 LEDs	5LEDS	6LEDs
Vin=12V						
Iout=350mA	76%	89%	93.5%			
Vin=18V						
Iout=350mA		83.5%	90%	95%	90%	
Vin=24V						
Iout=350mA			86.5%	90%	94.5%	97.5%

Application described in AN 1891

Application Example L597x:
MR-16: Halogen socket LED replacement Solution



- LED bulb based on halogen MR16.
- Solution has very small footprint.
- ST's solution uses the L5970.
- This board is intended to work with a $12V_{AC}$ input (works 4.4V < Vin < 36V).
- This board is shown driving a single 3W white LED.
- The board can also drive a 1W or future higher wattage LED with some resistor changes.
- Order Code: STEVAL-ILL007V1
- Application Note AN2259



Application Example L5973AD: 1000 lumen OSTAR LED Driver

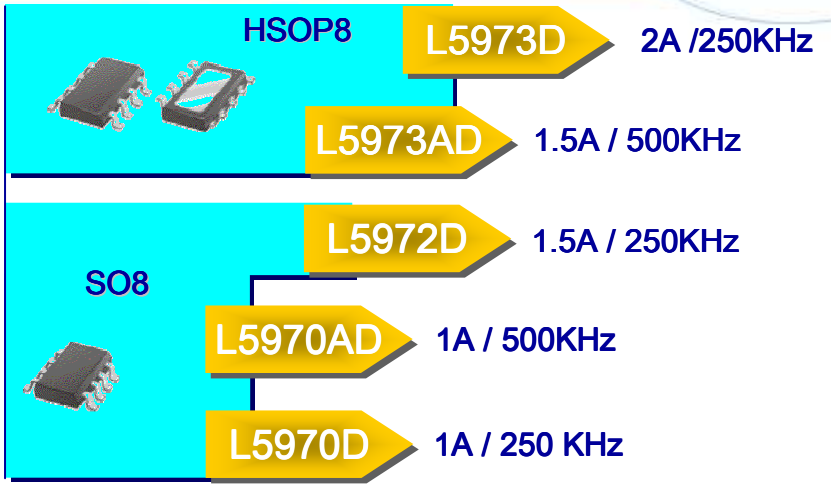
Main Characterisitics:

- Input voltage Vin: 5 - 30V DC (limited by transil)
- Switching Frequency 500KHz
- Output current: Iout = 1A, optionally 350mA or 700mA by jumper setting
- Output voltage Vout < Vin
- Short circuit, over temperature protection
- Drives 1000 lumen OSTAR with 1A at Vin>24V

Demoboard

L597x Family

- More than 2A in small SO8 package with minimum external component count
- P-channel power MOS: no bootstrap capacitor
- Wide input voltage range (4.4V up to 36V)
- High switching frequency (250KHz/500KHz, sync up to 700KHz*)
- Inhibit pin*
- Embedded protection features
- Typ R_{DSon}=250mΩ

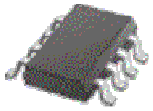


Suggested when Vin>18V

Device	Package	Ipk [A]	Iout [A]	Vin (V)	Vout (V)	Fsw [KHz]	Extra functions
L5970D	SO8	1.5	1	4.4V to 36V	0.5V to Vin	250	Inhibit, Vref, Sync
L5970AD	SO8	1.5	1	4.4V to 36V	0.5V to Vin	500	Inhibit, Vref, Sync
L5972D	SO8	2	1.5	4.4V to 36V	1.23V to Vin	250	-
L5973AD	HSOP8	2	1.5	4.4V to 36V	0.5V to Vin	500	Inhibit, Vref, Sync
L5973D	HSOP8	2.5	2	4.4V to 36V	0.5V to Vin	250	Inhibit, Vref, Sync

* all but L5972D

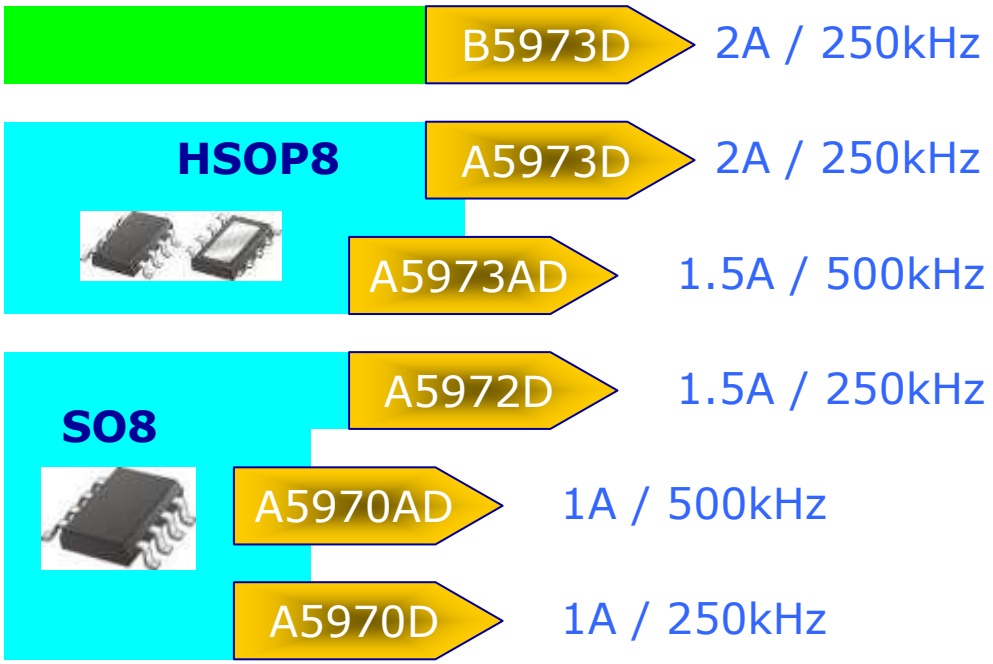
HSO8 - Rth j-amb 40C/W



SO8 - Rth j-amb 115C/W
Rth j-amb 62C/W for L5972D

DC-DC converters – A597xD for Automotive

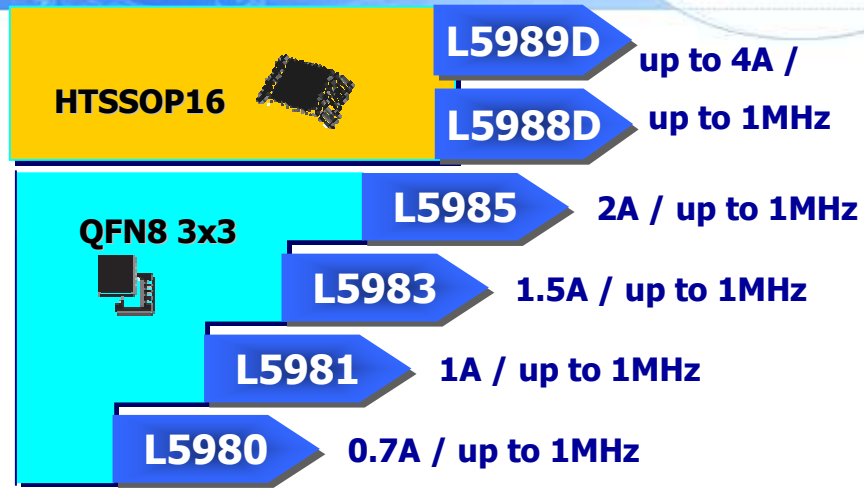
- More than 2A in small SO8 package with minimum external component count
- P-channel PowerMOS: no bootstrap capacitor
- Wide input voltage range: 4V up to 36V
- High switching frequency: 250kHz /500kHz
- Inhibit pin
- Embedded protection features
- Operates over the -40℃ to +125℃ temperature range
- BURN-IN test for high reliability (B5973D)



Device	Package	Ipk (A)	Iout (A)	Vin (V)	Vout (V)	Fsw (kHz)	Toperating	Extra functions
A5970D	SO8	1.5	1	4V to 36V	0.5V to Vin	250	-40℃ to +125℃	Inhibit, Vref, Sync
A5970AD	SO8	1.5	1	4V to 36V	0.5V to Vin	500	-40℃ to +125℃	Inhibit, Vref, Sync
A5972D	SO8	2	1.5	4V to 36V	1.23V to Vin	250	-40℃ to +125℃	-
A5972AD	HSOP8	2	1.5	4V to 36V	0.5V to Vin	500	-40℃ to +125℃	Inhibit, Vref, Sync
A5973D	HSOP8	2.5	2	4V to 36V	0.5V to Vin	250	-40℃ to +125℃	Inhibit, Vref, Sync
B5973D	HSOP8	2.5	2	4V to 36V	0.5V to Vin	250	-40℃ to +125℃	Inhibit, Vref, Sync

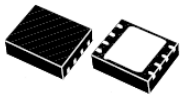
L598X Family

- More than 2A in small QFN3x3-8L package with minimum external component count
- P-channel power MOS: no bootstrap capacitor
- Wide input voltage range (2.9V up to 18V)
- High switching frequency (250KHz, adjustable up to 1MHz) with Synchronization capability
- Internal Soft-start
- Inhibit pin
- Embedded protection features
- Suitable for MLCC output filter
- Typ R_{DSon}=140mΩ



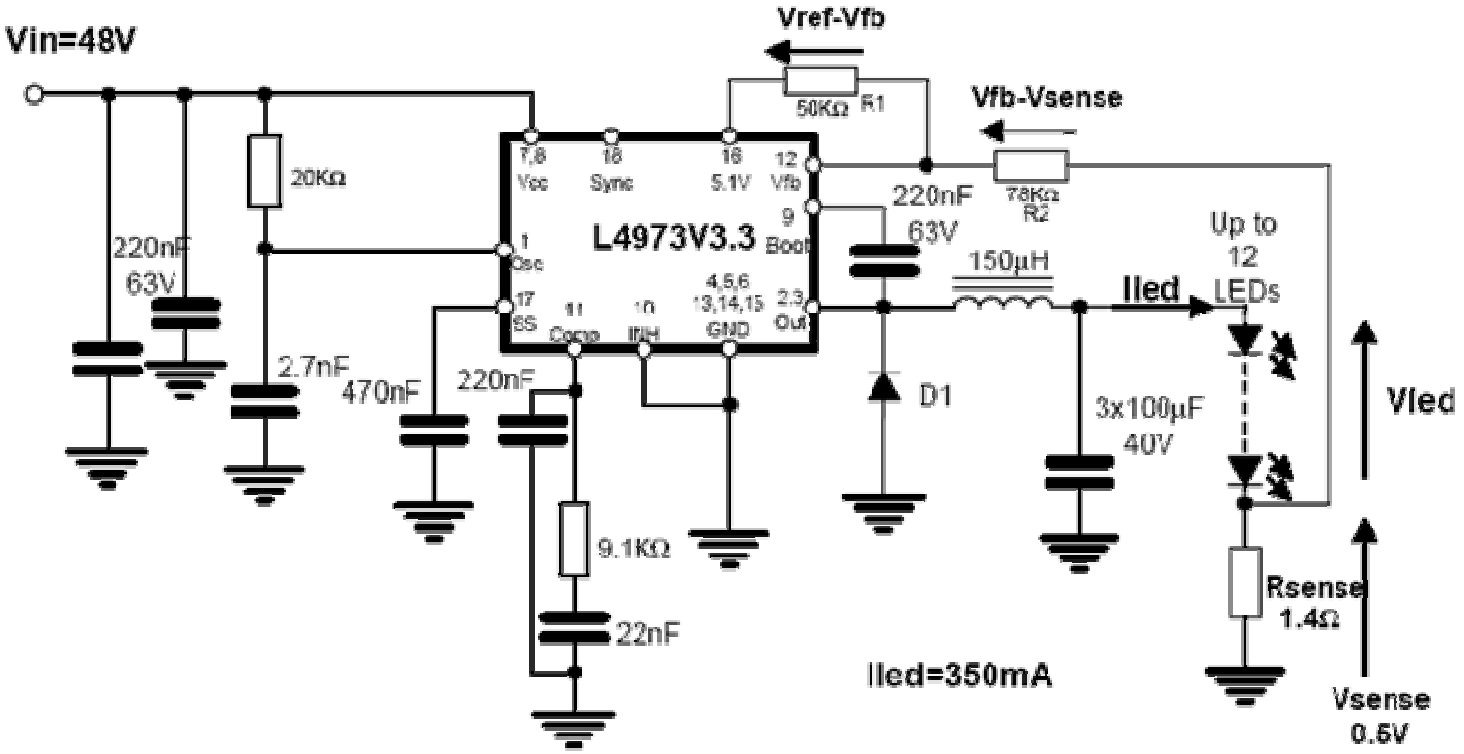
Suggested when Vin<18V

Device	Package	Ipk (A)	Iout (A)	Vin (V)	Vout (V)	Fsw (kHz)	Extra Functions
L5980	QFN3x3-8L	1	0.7	2.9V to 18V	0.6V to Vin	250	Inh, AdjFsw, Sync
L5981	QFN3x3-8L	1.5	1	2.9V to 18V	0.6V to Vin	250	Inh, AdjFsw, Sync
L5983	QFN3x3-8L	2	1.5	2.9V to 18V	0.6V to Vin	250	Inh, AdjFsw, Sync
L5985	QFN3x3-8L	2.5	2	2.9V to 18V	0.6V to Vin	250	Inh, AdjFsw, Sync



QFN 3x3 8L - Rth j-amb 60°C/W

L497x Application



Circuit for driving up to 12 LEDs

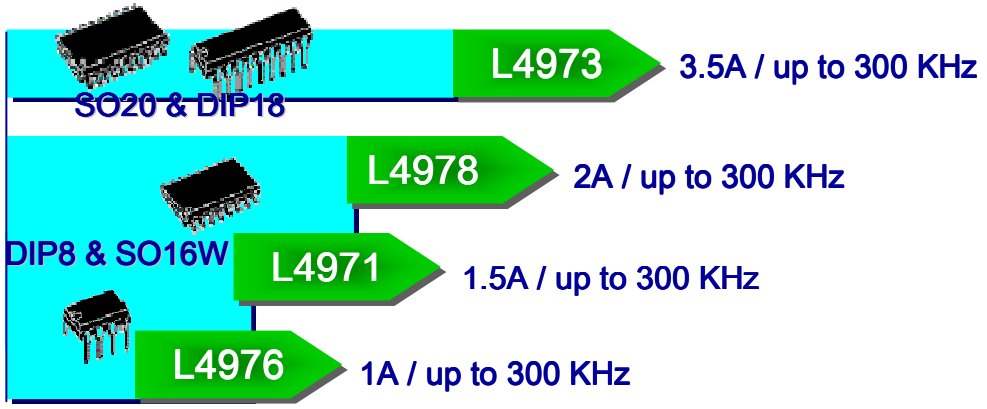
Efficiency	8 LEDs	10 LEDs	12 LEDs
Vin=48V			
Iout=350mA	95%	96%	98%

Application described in AN 1891

L497x Family

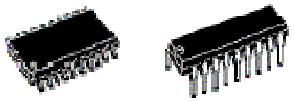
- Up to 3.5A available both in DIP and SO packages
- Wide voltage input range (8V up to 55V) and output range (0.5V up to 50V)
- Internal current limit
- Inhibit pin*
- OVP*
- External reference**

Suggested When Vin>36V and Iout>2A



Device	Package	Ipk [A]	Iout [A]	Vin (V)	Vout (V)	Fsw [KHz]	Extra functions
L4976	DIP8, SO16W	1.5	1	8V to 55V	0.5 to 50	up to 300	Vref
L4971	DIP8, SO16W	2	1.5	8V to 55V	3.3 to 50	up to 300	Inhibit
L4978	DIP8, SO16W	2.5	2	8V to 55V	3.3 to 50	up to 300	Inhibit
L4973 v.3.3	DIP18, SO20	4	3.5	8V to 55V	0.5 to 50	up to 300	Inhibit, Vref, Sync
L4973 v.5	DIP18, SO20	4	3.5	8V to 55V	5.1 to 50	up to 300	Inhibit, Vref, Sync

* all but L4976 , **L4976 and L4973



DIP18 & SO20

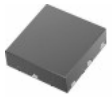
DIP8 & SO16W

ST1S10
3A Step-Down DC-DC with Synchronous Rectification

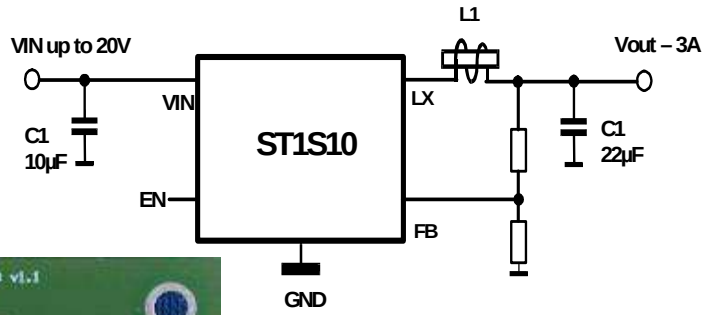
Main Characteristics:

- PWM fixed frequency 900KHz. It can be ext synch from 0.4 to 1.2MHz
- Output Current Capability: 3A max over all operating conditions
- Output Voltage: Adjustable from 0.8V feedback voltage
- Ceramic Capacitors and small Inductor
- 3.3V, 5V Fixed Output Voltages under customer request
- Max Operating Input voltage up to 18V
- Soft-Start circuit to reduce inrush current
- Efficiency: up to 90%
- Fast Transient Response
- Available with logic control Electronic Shutdown
- PPAK and DFN Packages

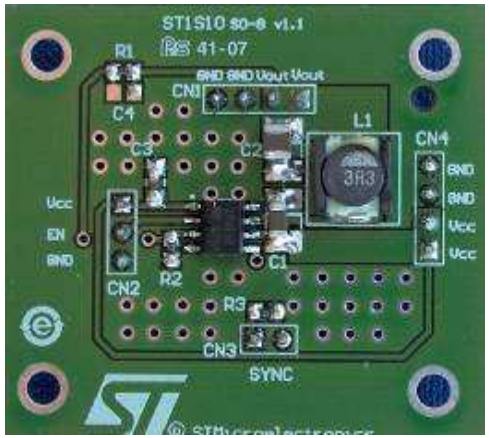
SO-8 Exposed Pad



DFN – 8L
4x4mm



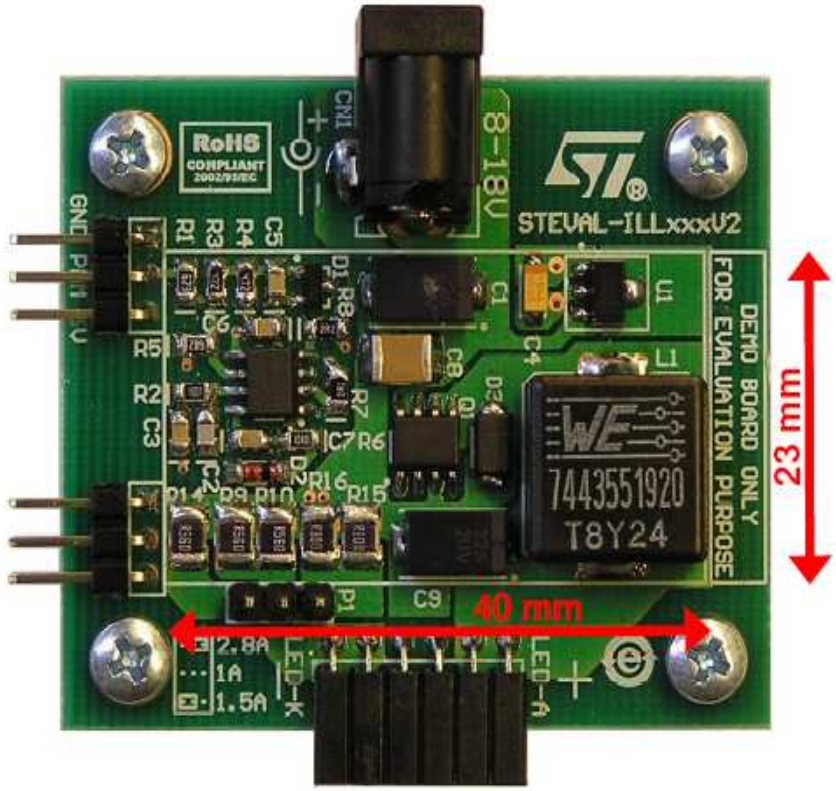
- Evaluation board with voltage output:



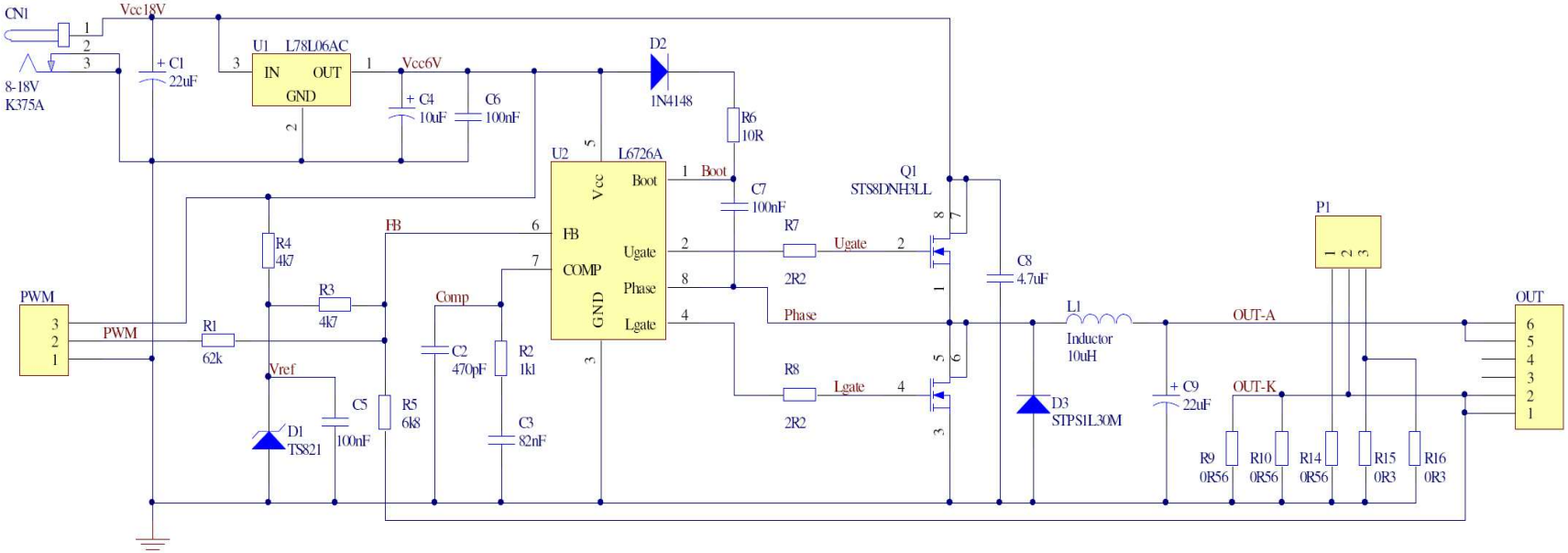
STEVAL-ISA044V1
STEVAL-ISA044V2

High Current LED Driver: Controller + PMOS

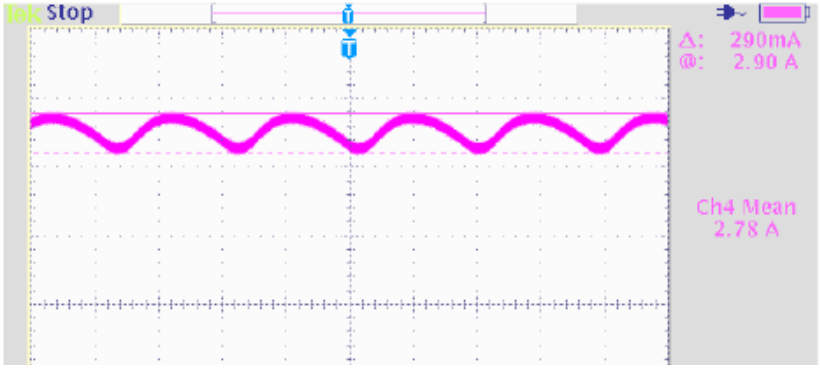
- **Vin: 8 – 18V**
- **Vout: 2.5 – 14V**
- **Iout: 1A. 1.5A, 2.8A, only limited by MOSFET and current sense resistors**
- **PWM and analog dimmable through interface**
- **High efficiency due to synchronous rectification**
- **Very compact**
- **Key components:**
  - L6726
  - STS8DNH3LL
- **Tools:**
  - STEVAL-ILL023V1 coming soon
  - AN in preparation



High Current LED Driver: Controller + PMOS



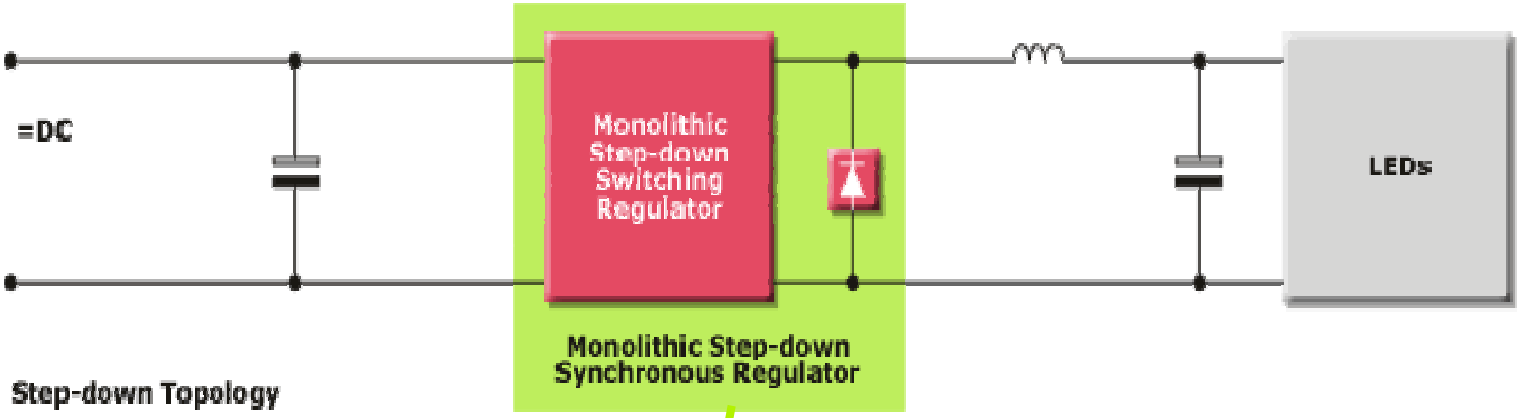
- **Schematic**
- **Output current with 1 x 2.8A LED**



Step Up Solutions

Step-down topology

Signage, Torch, portable lighting



Step-down Topology

L6902
L597X
L497X
ST1Sxx

L6925
L6926

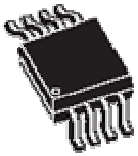
Application notes

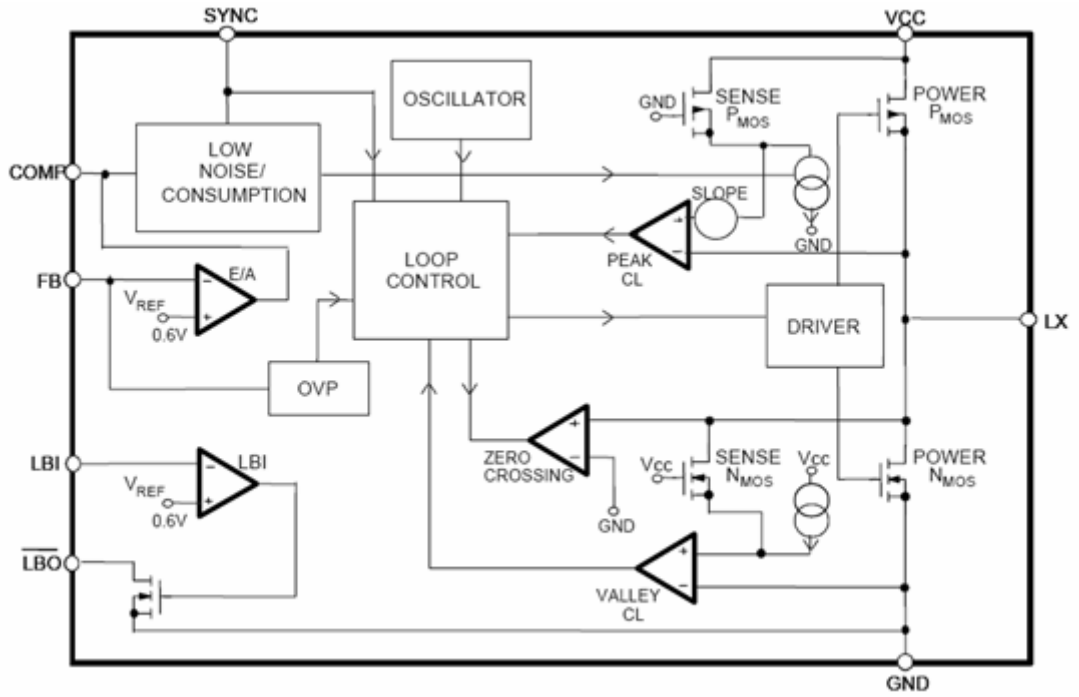
AN1891
AN1941

L6925 – L6926

Monolithic synchronous converter

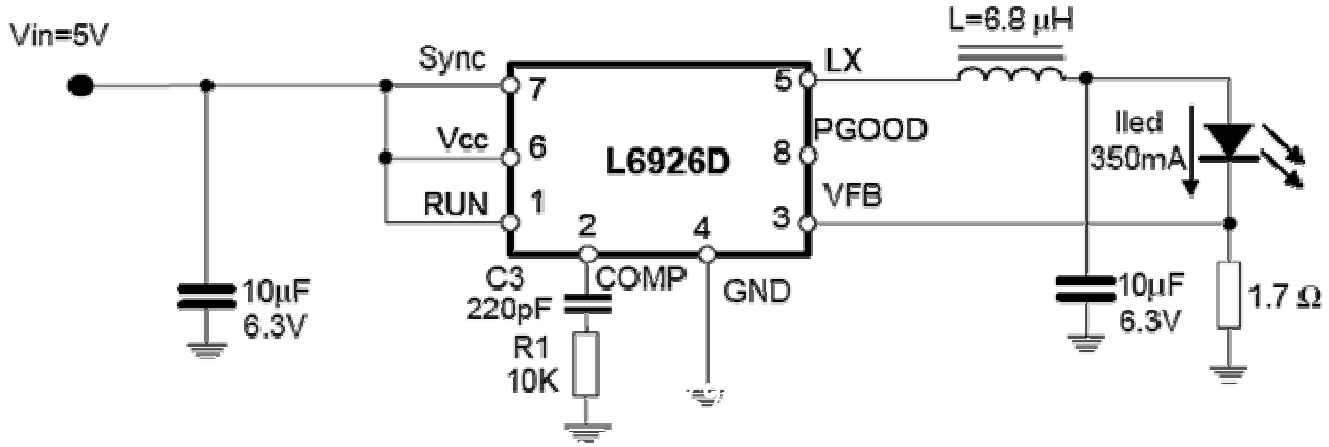
- High efficiency monolithic step down regulator
- Operating input voltage 2V – 5.5V (battery supplied applications)
- No external Schottky required – minimized external component count
- 600kHz switching frequency
- Externally synchronizable from 500kHz – 1.4MHz
- MSOP8 package
- 800mA maximum current
- Overcurrent protection





L6925 – L6926 Application

Monolithic synchronous converter



Vin (V)	5	5.5	5.96
Eff (%)	85	84	84

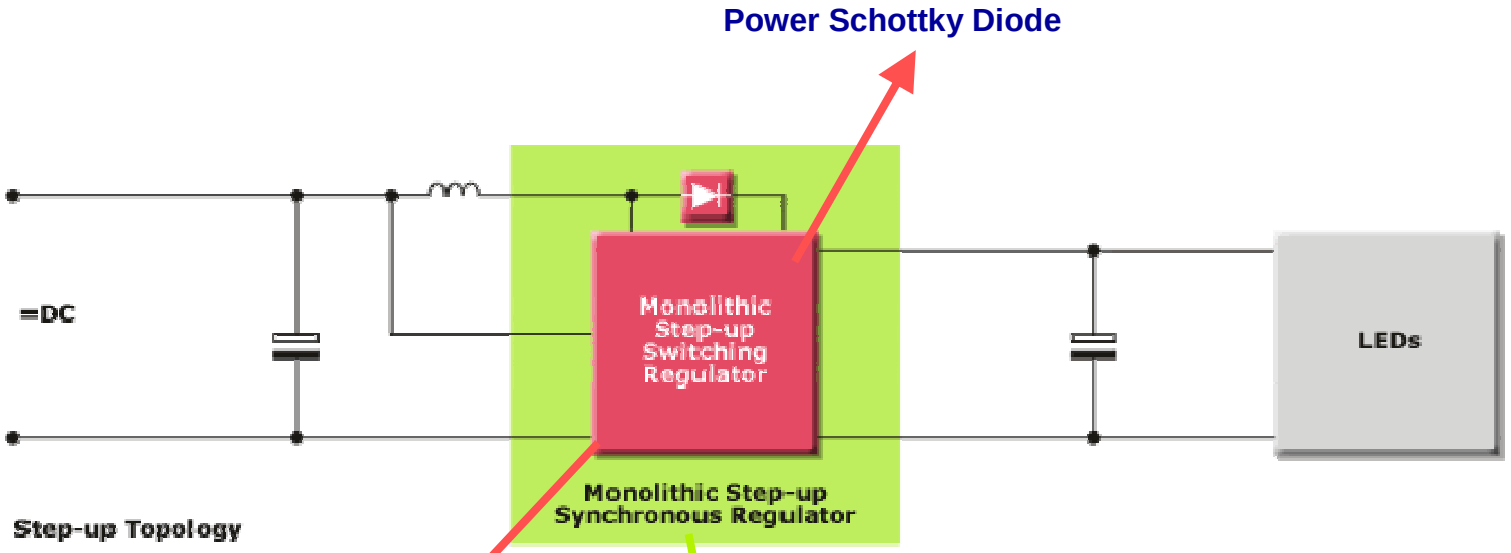
L6926D in buck topology supplied by 5V for 1 high brightness LED

Application described in AN 1891

More LED applications in AN 1941

Step-up topology

Signage, Torch, portable lighting



STLD20D
STLD40D

L6920D
L6920DB

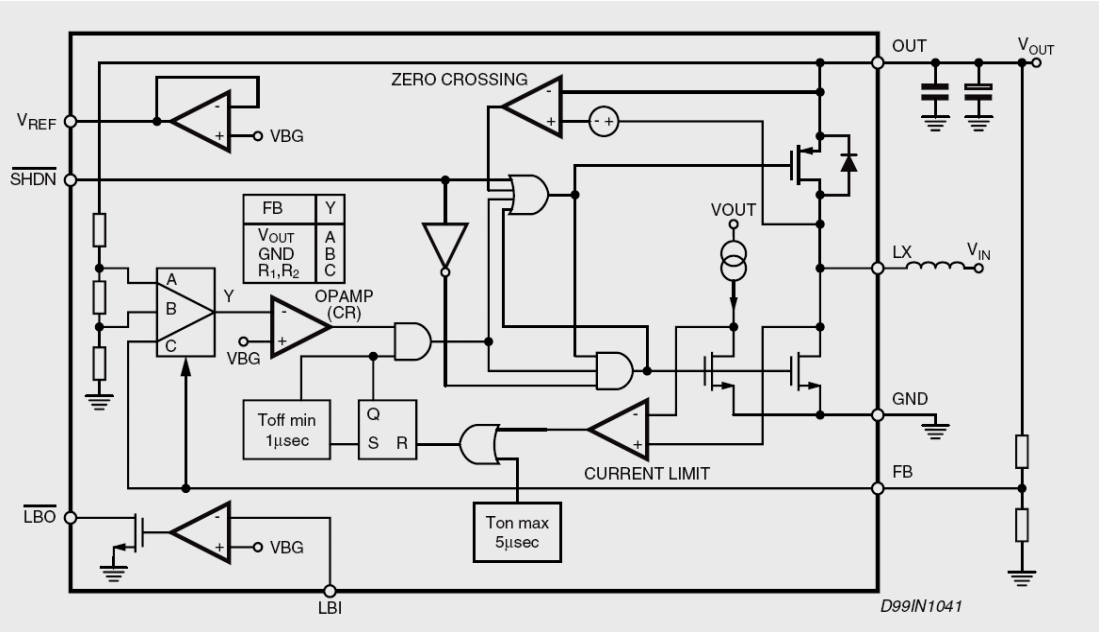
Application notes

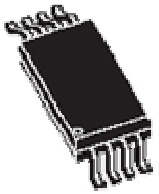
AN1891
AN1941

L6920
1V START-UP SYNCHRONOUS STEP UP CONVERTER

Features

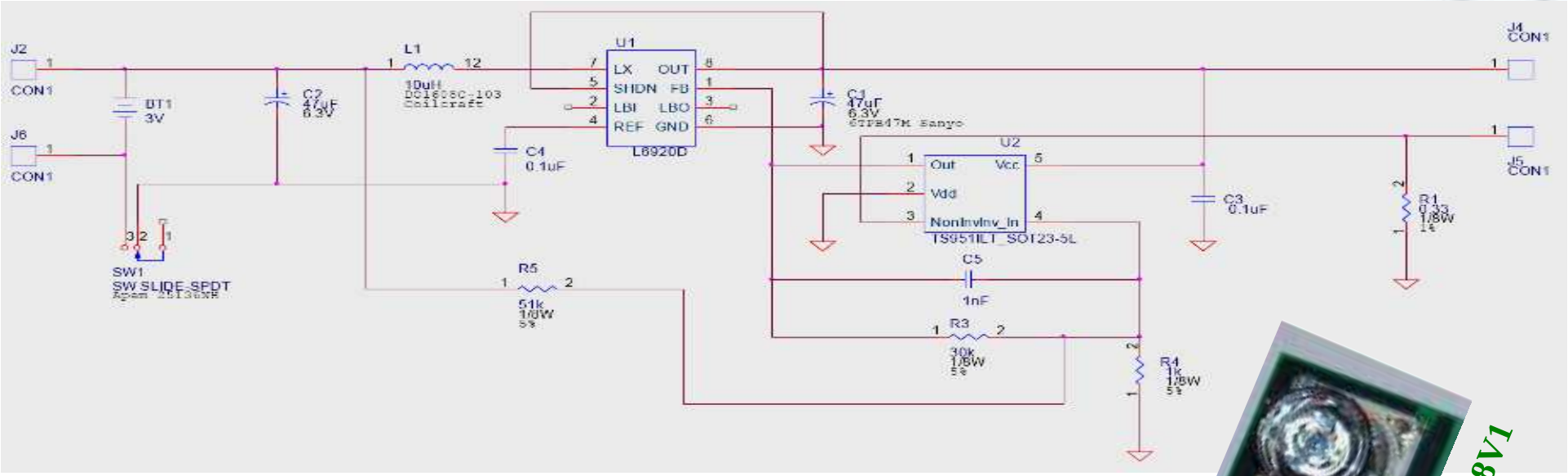
* 0.6 TO 5.5V OPERATING INPUT VOLTAGE
* 1V START UP INPUT VOLTAGE
* INTERNAL SYNCHRONOUS RECTIFIER
* ZERO SHUT DOWN CURRENT
* 3.3V AND 5V FIXED OR ADJUSTABLE OUTPUT VOLTAGE (2V UP TO 5.2V)
* 120mΩ INTERNAL ACTIVE SWITCH
* LOW BATTERY VOLTAGE DETECTION
* REVERSE BATTERY PROTECTION

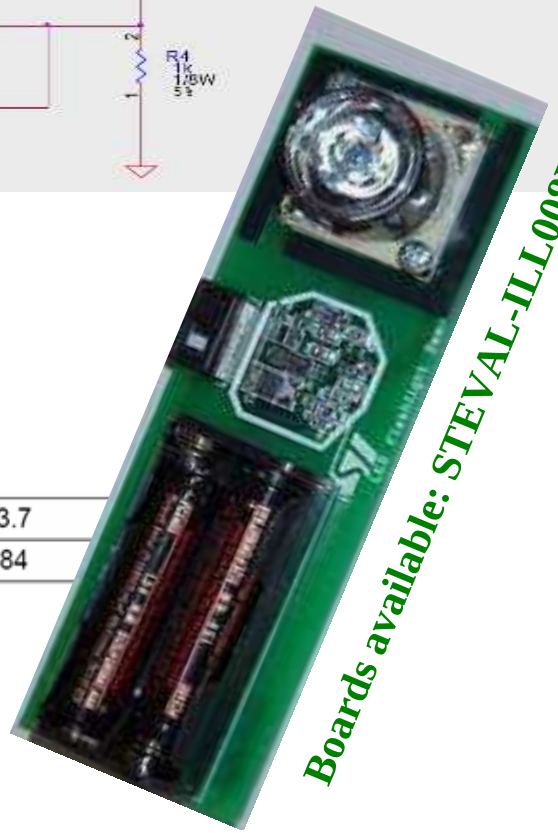




TSSOP8

STEVAL-ILL008V1 - L6920 Application





Boards available: STEVAL-ILL008V1

- achievable 1A output current
- 1 LED can be driven with 700mA output current (Vf = 4.4V)
- 1 LED can be driven with 350mA output current (Vf = 4V)

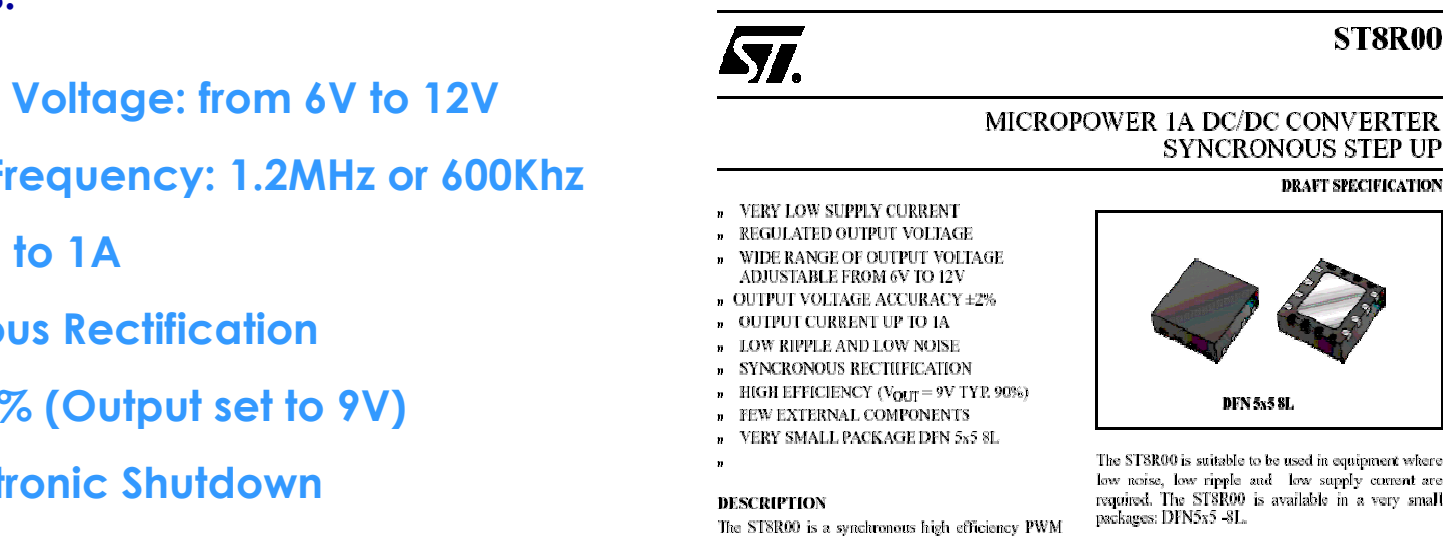
Vin (V)	2	2.5	3	3.5	3.7
Eff (%)	88	88	90	86	84

Application described in AN 1891
More LED applications in AN 1941

ST8R00
1A, DC-DC , Synchronous Step-Up Converter

Main Characteristics:

- Adjustable Output Voltage: from 6V to 12V
- DC-DC Switching Frequency: 1.2MHz or 600Khz
- Output Current: up to 1A
- Internal Synchronous Rectification
- Efficiency up to 90% (Output set to 9V)
- Logic Control Electronic Shutdown
- Output Current CUT-OFF when in shutdown



ST8R00

MICROPOWER 1A DC/DC CONVERTER
SYNCRONOUS STEP UP

DRAFT SPECIFICATION

- VERY LOW SUPPLY CURRENT
- REGULATED OUTPUT VOLTAGE
- WIDE RANGE OF OUTPUT VOLTAGE ADJUSTABLE FROM 6V TO 12V
- OUTPUT VOLTAGE ACCURACY ±2%
- OUTPUT CURRENT UP TO 1A
- LOW RIPPLE AND LOW NOISE
- SYNCRONOUS RECTIFICATION
- HIGH EFFICIENCY (V_{OUT} = 9V TYP. 90%)
- FEW EXTERNAL COMPONENTS
- VERY SMALL PACKAGE DFN 5x5 8L

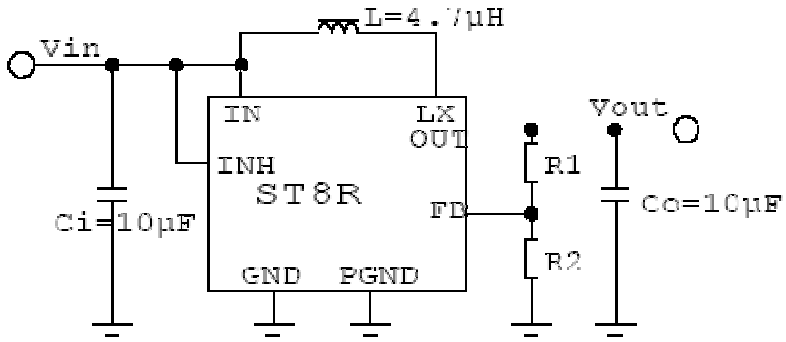
DFN 5x5 8L

DESCRIPTION

The ST8R00 is a synchronous high efficiency PWM

The ST8R00 is suitable to be used in equipment where low noise, low ripple and low supply current are required. The ST8R00 is available in a very small packages: DFN5x5 -8L.

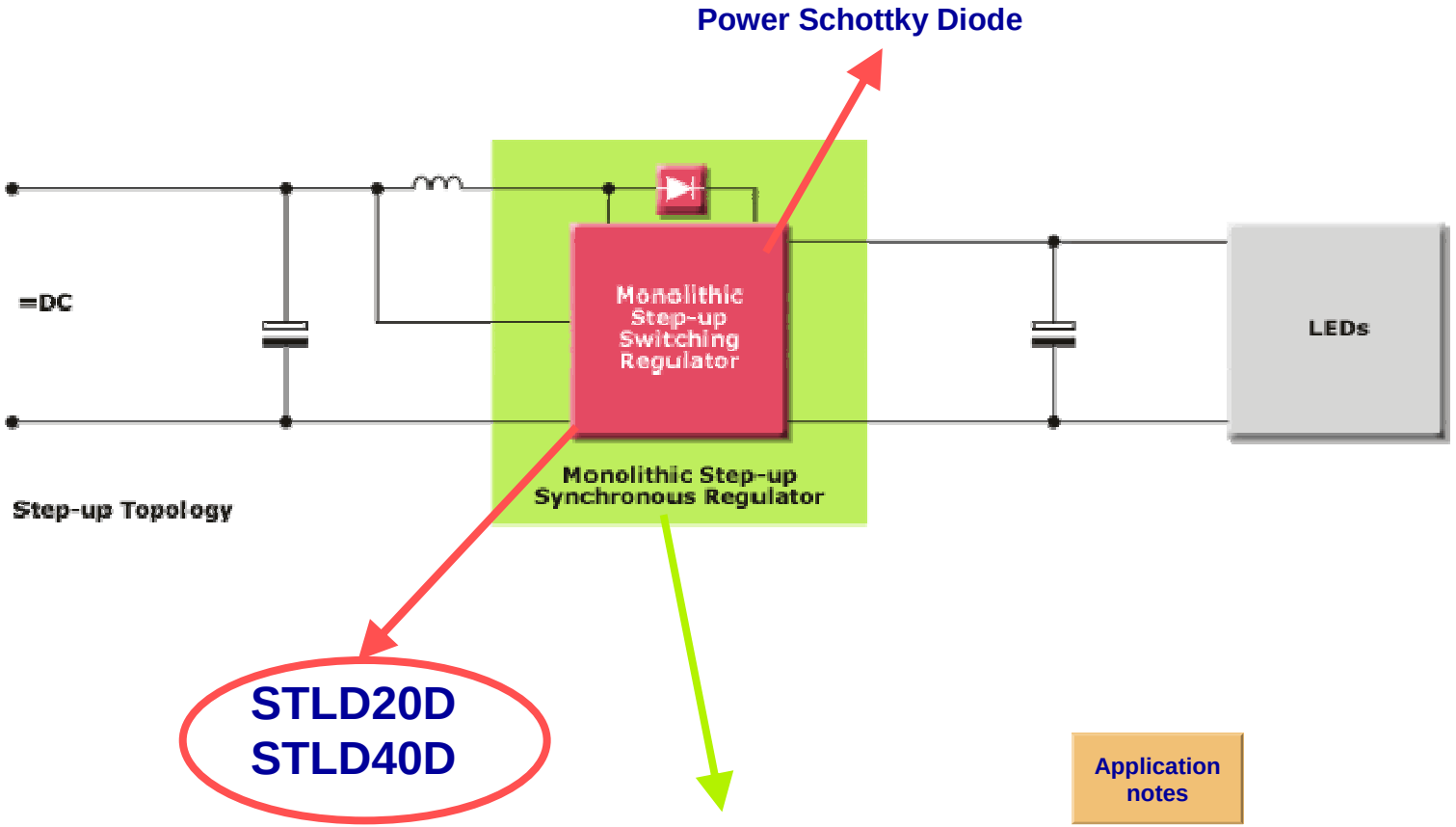
QFN 4X4MM -8L



Demo board available on request

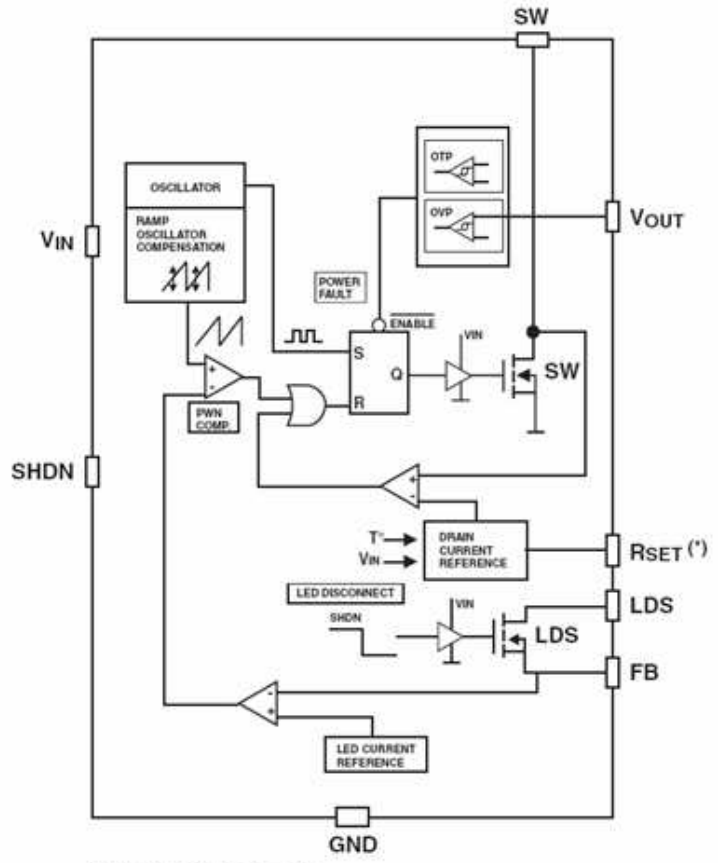
Step-up topology

Signage, Torch, portable lighting



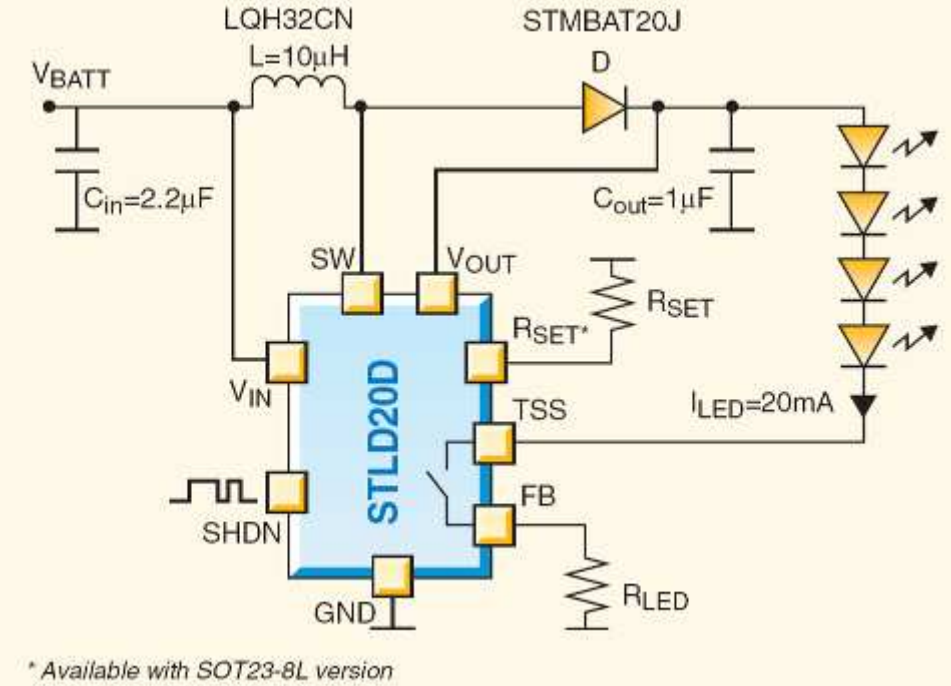
STLD20D / STLD40D

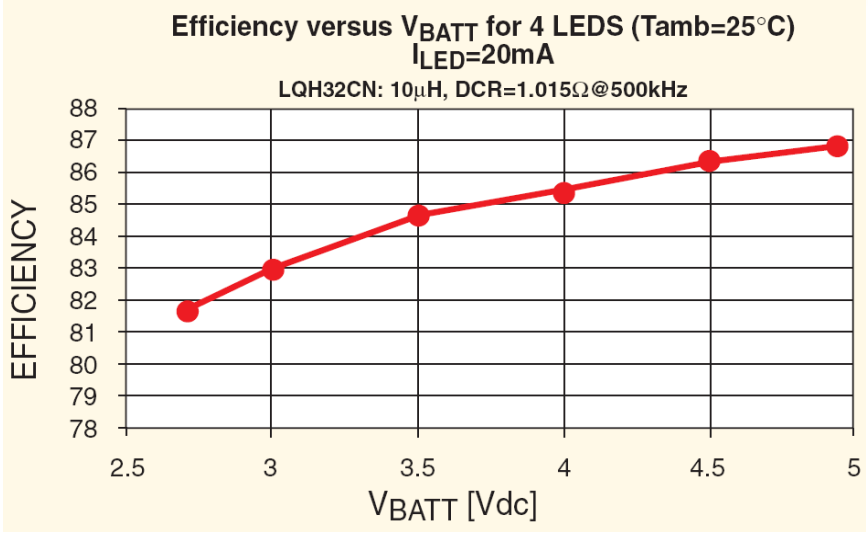
- **STLD20D drives 4 and STLD40D drives 10 white LEDs from battery voltage supply.**
- **Constant LED current regulation**
- **High efficiency over extremely wide range of battery voltage**
- **LED branch isolation switch (STLD20 only)**
- **Over voltage and over temperature protection**
- **Dynamic battery voltage variation compensation.**
- **Soft start.**
- **Shut-down mode with dimming control.**
- **Smal packages**



(*) STLD20D-C8 only

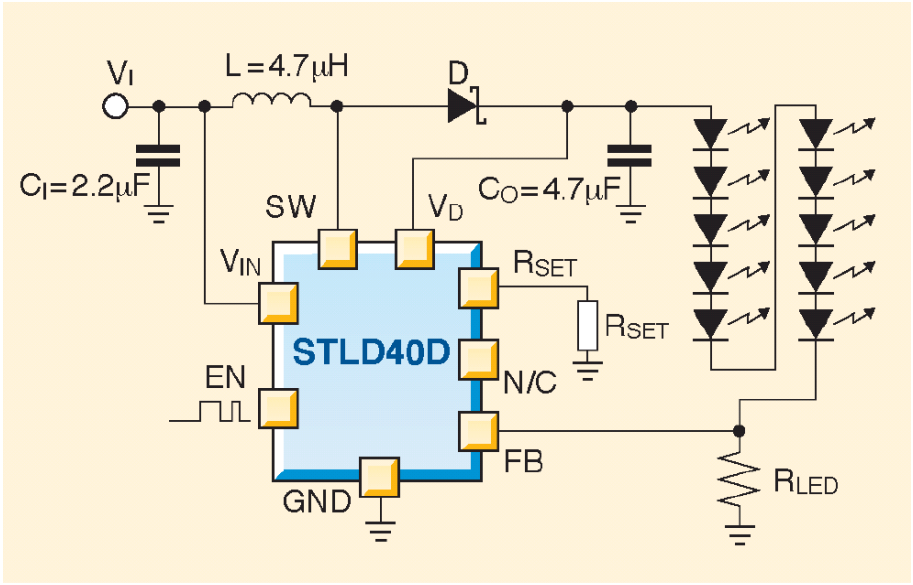
STLD20 Application



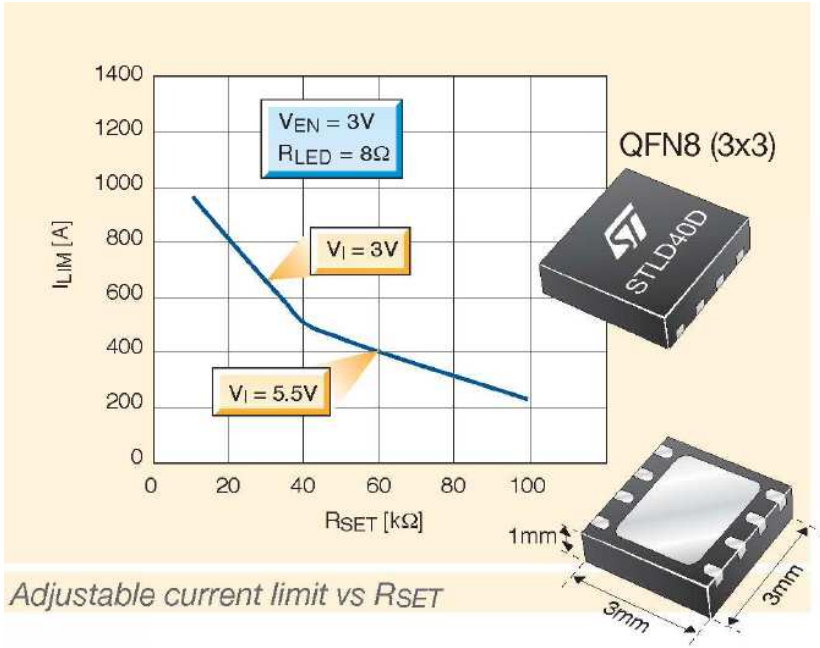


- White Led supply for LCD backlight
- Mobile phone
- PDA and organizers
- Any handsets powered from 2.8V to 4.2V
- Maximum output voltage **18,5V** (internally limited)
- 5 white LEDs can be driven with 20mA output current (Vf = 3,5V)

STLD40 Application



STLD40D typical application circuit



Adjustable current limit vs RSET

- White Led supply for LCD backlight
- Any handsets powered from 3.3V to 4.8V
- PDA and organizers
- Mobile phone
- Maximum output voltage **37V**
- 10 white LEDs can be driven with 20mA output current (Vf = 3,5V)

Evaluation board: STEVAL-TLL001V1	AN2333

Linear solution to drive LEDs

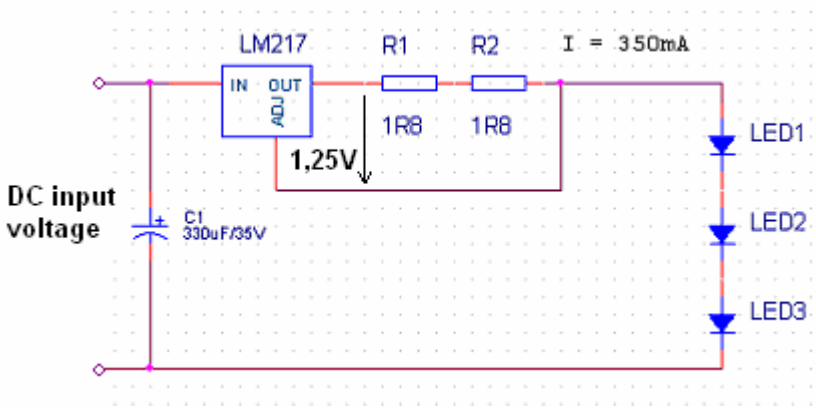
Linear solution with high power dissipation on resistor using LM217

Advantage:

- Low cost solution
- Easy design
- Less components is used
- Output voltage range: 1.25V to 37V
- Maximum output current 1.5A

Disadvantage:

- Efficiency
- Power losses on resistor



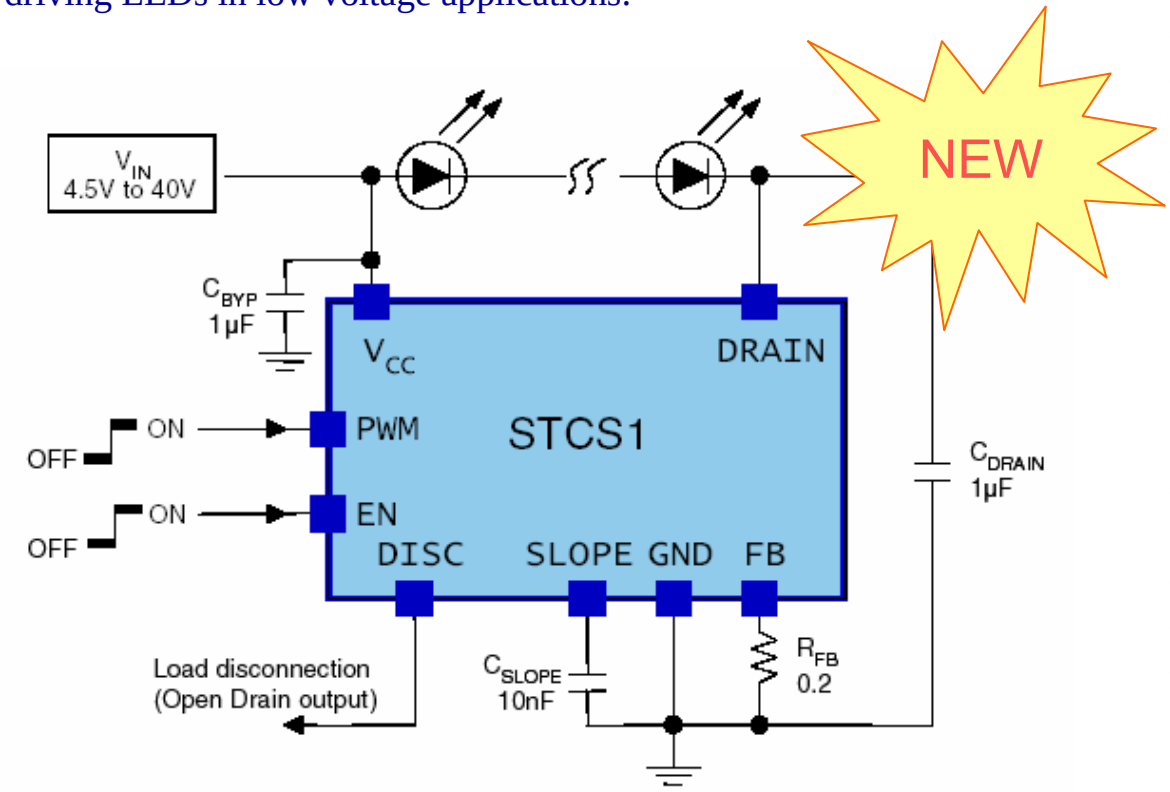
R = R1 + R2 = U_adj / I_led

U_adj = 1.25V

1.5A Max constant current LED driver

Description:

The STCS1 is a BiCMOS constant current source designed to provide a precise constant current starting from a varying input voltage source. The main target is to replace discrete components solution for driving LEDs in low voltage applications.



Features:

- Up to 40V input voltage
- Less than 0.5V voltage overhead
- Output current setting between 1mA and 1.5A; precision +-10%
- PWM Dimming pin up to 50kHz
- Shutdown pin
- LED disconnection diagnostic
- Slope control with external cap for controlling current rise from tens of microseconds to tens of milliseconds allowing reduction of EMI

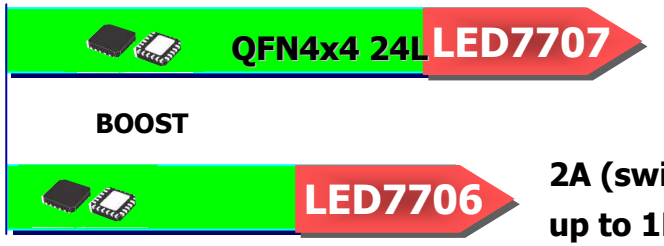
Applications:

- LED constant current supplying for varying input voltages
- Low voltage lighting
- Small appliances LED lighting
- Car LED lights

- **LED7706/7 backlight and emergency lighting**

LED770x family for LCD Backlight and Emergency Lighting

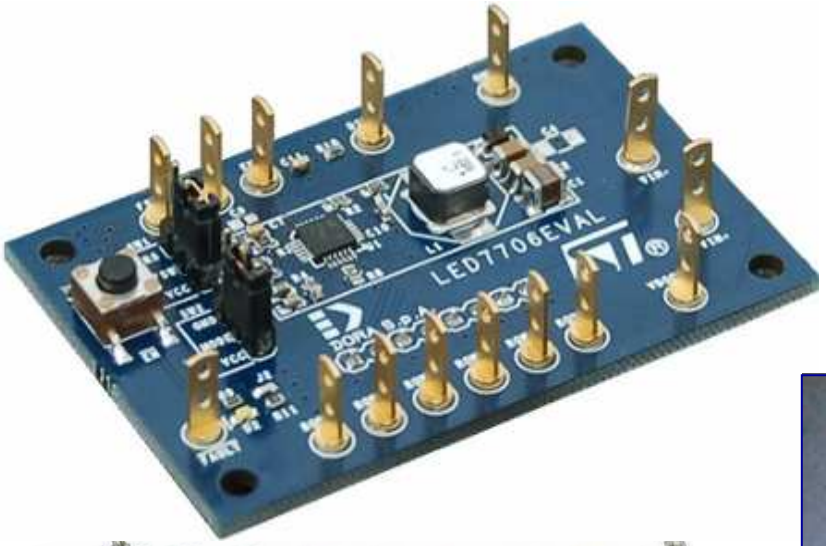
VIN from 4.5V to 36V

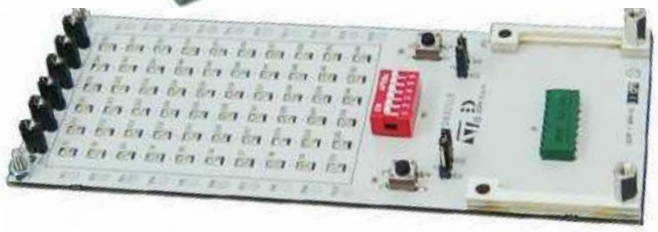


2A (switch) up to 85mA for each row up to 1MHz

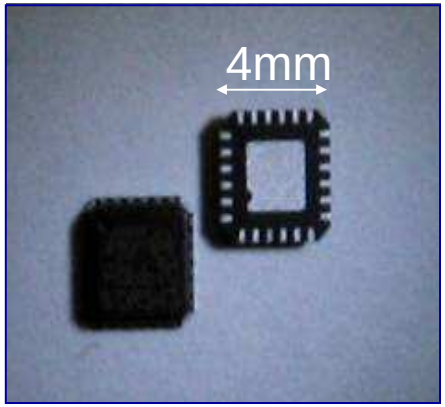
Available soon

2A (switch) up to 30mA for each row up to 1MHz

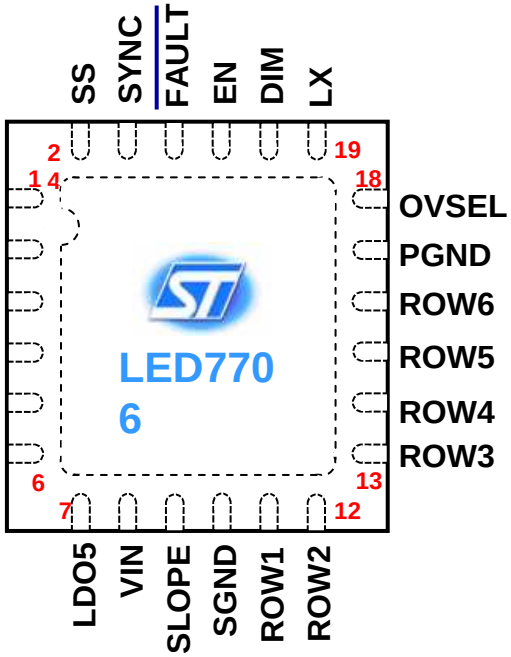




Example of LED load board



VFQFPN 4x4 – 24

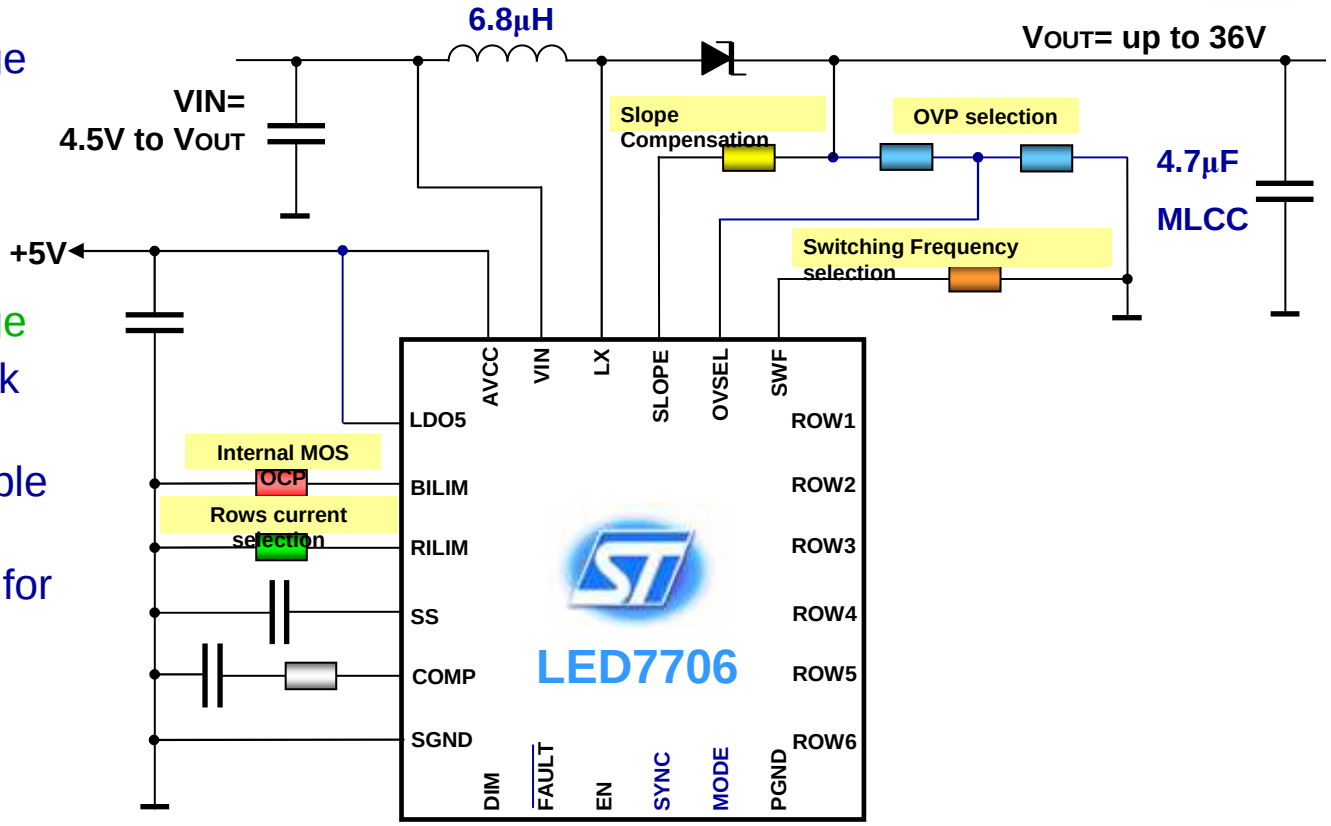


Top view

LED7706-7 Key Features

Boost Section

- 4.5V To 36V Input Voltage Range
- Internal Power MOSFET
- Internal +5V LDO for device supply
- Up To 36V Output Voltage
- Constant Frequency Peak Current-mode Control
- 200kHz to 1MHz adjustable switching frequency
- External synchronization for Multi-device Application
- Pulse-skip power saving mode at light load
- Programmable Soft-start
- Programmable OVP protection
- Thermal Shutdown
- Suitable for MLCC Output Filter

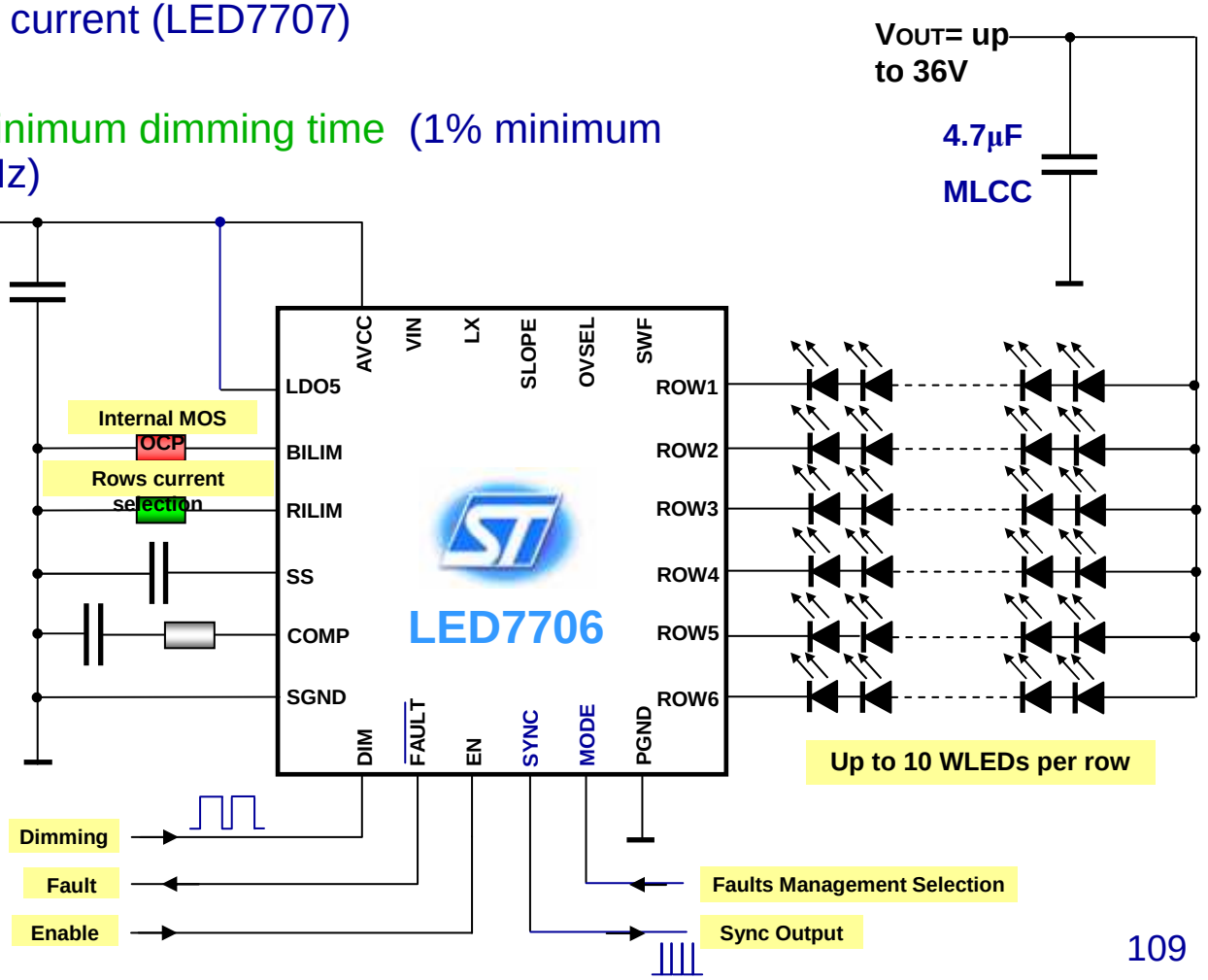


LED7706-7 Key Features

Backlight driver Section

- Six rows with 30mA (85mA)* maximum current capability (Adjustable)
- Up to 60 White LEDs
- Parallelable rows for higher current (LED7707)
- Rows disable option
- Less than 500ns (10µs)* minimum dimming time (1% minimum dimming duty-cycle at 20kHz)
- ±2% current matching between rows
- LED failure (open and short circuit) detection

(* LED7707 only)



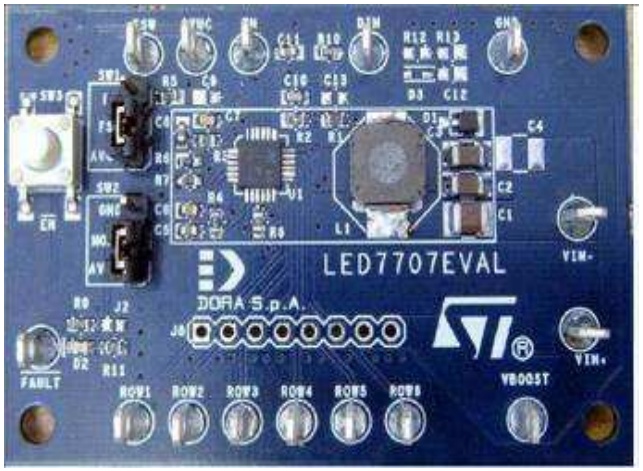
EVALED7707

6-rows 85mA LEDs driver with boost regulator for LCD panels backlight

In stock soon

Documentation: AN2810 publishing in progress

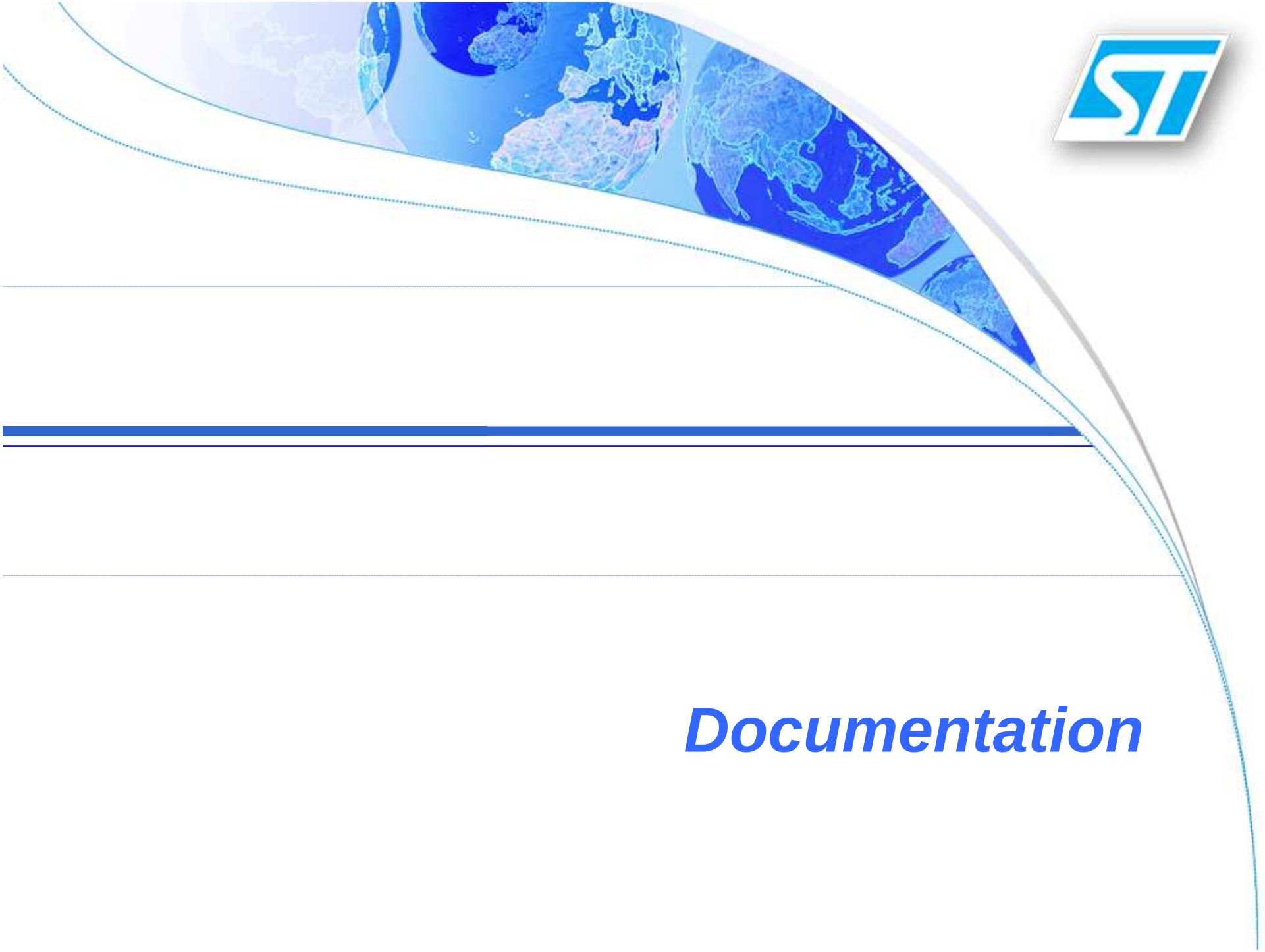
- LED7707 (VFQFPN-4x4) driver onboard set for 60mA/channel.
- 4.5V to 32V input voltage range.
- Up to 10 White-LEDs (36V) in series on each channel.
- Selectable switching frequency (660kHz or 825kHz).
- Selectable fault management.
- Onboard test point for each important signal for laboratory evaluation.
- Onboard reset button.
- 8-pins header for external LEDs array connection.
- Fault LED indicator.



Key Product:
✓ LED7707 (VFQFPN-4x4)

Typical Applications:
✓ LCD monitors & TV Panels
✓ PDAs Panel Backlight
✓ GPS Panel Backlight
✓ Emergency Lighting

Board Purpose:
Compact solution with high dimming and control performance for driving LEDs in not only 6 strings 85mA each, but even one string at 500mA.



Documentation

Demo/Evaluation boards overview

LED dedicated:

STP24DP05 - order code: STEVAL-ILL015V1
STP16CP05 - order code: STEVAL-ILL003V2
STP08DP05 - order code STEVAL-ILL002V3/4
STP04CM05 - order code: STEVAL-ILL009V5
order code: STEVAL-ILL009V3 (LOAD board with LEDs)
order code: STEVAL-ILL009V4 (LOAD board with LEDs)
L6902D - order code: STEVAL-ILL010V1
Coming soon: L6726+STS8DNHLL – order code: STEVAL-ILL023V1

L6920 - order code: STEVAL-ILL008V1
L5973D driver for MR-16 - STEVAL-ILL007V1

STLD40 - order code: STEVAL-TLL001V1

STCF01 - order code: STEVAL-TLL002V1 (coming soon)

STCF02 - order code: STEVAL-TLL003V1 (coming soon)
LED7706/7 - order code: EVALED7706/7

VIPer12A - order code: STEVAL-ILL005V1
New VIPer17 - order code: STEVAL-ILL017V1

VIPer22A - order code: STEVAL-ILL006V1

VIPer22A with DALI connector - STEVAL-ILL001V1
Coming soon: L6562A – order code STEVAL-ILL013V1
Osram Dragon LEDs: - order code STEVAL-ILL018V1/2/3/4

Demo/Evaluation boards Overview

General purpose boards:

L597x - order code: EVAL5970 or EVAL5973

L6902D - order code: EVAL6902

L497x - order code: EVAL4971 or EVAL4971D or EVAL4973

L6561 - order code: EVAL6561-80

L6562 - order code: EVAL6562-80

L6920 - order code: EVAL6920

Application Notes Overview
dedicated for LEDs

- DC/DC:
  - **AN 1891** / Application ideas - driving LEDs using L497x, L597x, L692x DC-DC converters families
  - **AN 1941** / Low voltage LED driver using L6920D, L4971 and L6902d
  - **AN 2129** / Dimmable LED driver using L6902D
  - **AN 2333** /White LED power supply for large display backlight using STLD40
  - **AN 2243** /Step up converter for camera flash light using STCF01
  - **AN 2304** /Designing a Flash LED driver using an STCF02 step-up/down current mode converter
  - **AN 2259** /High intensity LED driver using the L5970D/L5973D
  - **UM-ILL023** / High current 2.8A LED driver using L6726 *in preparation*
- Offline:
  - **AN 1916** / VIPower - Offline constant current LED driver using VIPer12/22A
  - **AN 2042** / VIPower: Dimmable driver for high brightness LEDs with VIPer22A
  - **AN 1060** / Flyback converters with the L6561 PFC
  - **AN 1059** / Design equations of high – power – factor flyback converters based on L6561
  - **AN 2067** / Dimmable white LEDs power supply with VIPer53
  - **AN 1734** / VIPer12A SINGLE OUTPUT REF. BOARD 85 TO 264 VAC INPUT, 6W OUTPUT
  - **AN 1934** / VIPer12A NON ISOLATED FLYBACK CONVERTER REFERENCE BOARD
  - **AN 1894** / VIPer12A NON ISOLATED BUCK AND BUCK-BOOST CONVERTER REF. BOARD
  - **AN2811** / VIPer17 based 2 W non-insulated Flyback LED driver
  - **UM0670** / 80W non-insulated offline LED driver with PFC and DC/DC converterbased on L6562A
  - **AN2838** / 35W High power insulated flyback LED Driver based on L6562A
- LED Matrix Display
  - **AN 2141** / STP16CP596 + L5970 + ST7Lite09 LED Array driver reference design
  - **AN 2415** / STP08CDC596 + L5970 + LE50 + ST7Lite39 LED error detection demo board
  - **AN 2478** / STP08DP05, STP16DP05 Normal mode and error detection features
  - **AN 2531** / Generating multicolor light using RGB LEDs with STP04CM596
  - **AN2841 / UM0574 / UM0588** / STP24DP05 + STM32F103 Array and Display driver reference design